INSPECTION

OF THE

MATERIALS AND WORKMANSHIP

EMPLOYED IN

CONSTRUCTION.

A Reference Book for the Use of Inspectors, Superintendents, and Others Engaged in the Construction of Public and Private Works.

CONTAINING

A COLLECTION OF MEMORANDA PERTAINING TO THE DUTY OF INSPECTORS; QUALITY AND DEFECTS OF MATERIALS; REQUISITES FOR GOOD CONSTRUCTION; METHODS OF SLIGHTING WORK;
ETC., ETC.

BY

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PREFACE.

DURING a long acquaintance with inspectors on public and private works I have been frequently asked to recommend a concise manual defining the duties of inspectors and describing the characteristics of the materials employed, the methods of preparing them, and the manner in which work is slighted; but I have felt myself unable to make a satisfactory selection, chiefly for the reason that the desired information is contained in the text-books of civil engineering and architecture mixed with scientific discussions that are of but little interest to any but the engineer or architect.

Therefore I have set myself the task of selecting and adapting the desired matter to the wants of inspectors and others engaged in supervising the construction of civil works.

The aim of this publication is to present in as concise a form as possible (1) the duties of the inspector; (2) the characteristics and defects of the materials used in construction; (3) a description of the methods employed in preparing the materials for use; (4) the manner of placing the prepared materials in the structure; and (5) to indicate the points to which the inspector must direct his especial attention to secure a faithful compliance with the plans and specifications.

While presenting the generally approved methods of preparing materials, etc., *it must be distinctly understood that the directions or suggestions set forth are not intended to run counter to, or be employed in opposition to, the directions and instructions given in the specifications under which the work is being prosecuted.*

Reference to authorities has not usually been given in the text; instead, a list of the various text-books and technical dictionaries consulted is given at the end of the book. To the authors of these works the writer desires to give his thanks and acknowledge his indebtedness for information and suggestions.

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INSPECTION OF THE MATERIALS AND WORKMANSHIP EMPLOYED IN CONSTRUCTION.

CHAPTER I.

DUTIES OF INSPECTORS.

THE duty of the inspector is to see that the work on which he is placed is constructed in accordance with the plans and specifications therefor and such written or verbal instructions as he may from time to time receive from his superior officer.

To perform his duty efficiently he must make himself thoroughly acquainted with the requirements of the specifications, a copy of which should always be in his possession.

The details of the inspector's duty will vary with the character of the work. In a general way it may be divided into three parts, as:

1. Inspection of the materials to be employed.
2. Inspection of the methods used in preparing the materials.
3. Inspection of the construction, or placing of the prepared materials in the structure.

To efficiently perform each of these functions the inspector must be familiar with the characteristics of the materials with which he has to deal, the methods employed in preparing and placing them in the work, and he must also know whether the finished work is what is required or expected.

In performing the first section of his duty the inspector is required to pass upon the quality of the materials delivered, and determine whether they meet the requirements of the specifications or not, rejecting all that are defective.

In marking rejected material he must be careful to so place the

marks that they cannot be readily erased. As a distinguishing mark, the letter "R" or "C" may be used.

It will not be sufficient only to mark the rejected material and rely upon its being removed by the contractor. He must see that *it is removed.* If this precaution is not taken, the chances are that part if not all of it will find its way into the work.

A careful record of all material rejected should be kept, stating the kind, character of the defects, and amount.

Under the second division of his duty the inspector has to watch the methods employed in preparing the materials, to see that the quantities called for are used, and that the dimensions of all manufactured pieces correspond to those marked on the plans.

The right of the inspector to require special methods of manufacture to be followed is not always clearly defined. It is customary to allow the contractor to follow his own methods, so long as such methods cause no injury to the material and produce the required results. But when such methods cause injury or fail to produce the required results the inspector should have them stopped.

To efficiently perform his duty under the third section the inspector must be familiar with the methods employed by the various craftsmen in executing their work.

To provide against slighting by careless and indifferent workmen constant vigilance is necessary, especially in such parts of the work which are difficult of access or will be covered up.

A close scrutiny of each workman's manner of doing his work will be a great aid in directing attention to defective workmanship. Every craftsman whose workmanship is once found defective should be closely watched, and if found to persist in doing defective work his removal should be ordered.

The specifications and plans for each particular work must be the inspector's guide as to the character of the materials and workmanship required, and in case of any discrepancy between them, or doubt as to the meaning of any of the clauses, the matter must be submitted without delay to the engineer or architect for an explanation.

The inspector should keep a diary recording the state of the weather, the number and trade of the workmen employed, the orders received and given, the amount and kind of material delivered, accepted, and rejected, the progress made, accidents, and any other incident which circumstances may suggest.

At the periods directed by his chief he will send in his report.

This report is made up from the record of daily events, and should give such full details, figures, and descriptions as will enable the chief to judge of the progress of the work.

The inspector should so arrange his work as to inconvenience the contractor as little as possible. He should be on hand at all times so that workmen can consult him about any questionable points as they arise, and in this way avoid a great deal of friction which might occur if they proceeded in the way that seemed best to them.

On the failure of the contractor or any of his workmen to comply with the requirements of the specifications, the inspector should notify him or his representative of the defective work and allow him a reasonable time in which to make it good. If at the end of this time the rectification is not made, or if he refuses to comply with the notice, the inspector must immediately acquaint his chief with the full particulars of the case, description of the defective work, character of the order given, and reasons advanced by the contractor for refusing to conform to it.

The inspector should avoid arguments and disputes, and before raising objections or making complaints he should be quite sure of his case, then in as few words as possible make the complaint known. When complaint is necessary it should be promptly made; the longer it is put off the more difficult will be the rectification.

The disagreements most frequent between inspectors and contractors and their agents are caused chiefly by complaints of the former of non-performance of the work in accordance with the specifications, and, on the part of the latter, complaints of undue severity. This complaint is to be expected; the best of men are reluctant to change what has already been done, and if inadvertence or temporary convenience has led them into an obvious violation of the specifications, they will mince the truth in their explanations and excuses.

The adjusting of these disagreements the inspector, unless he be possessed of a large fund of amiability and common sense, will find a very trying and unpleasant task. He who can distinguish between a mere blemish and a real defect, and thoroughly understands his position and can maintain it with firmness, will be less likely to have bad work thrust at him than one who errs in his decisions or is irresolute in his position.

CHAPTER II.

STRUCTURAL MATERIALS.

I. NATURAL STONES.

Classification of Stones.

The rocks from which the stones for building are selected are classified according to (1) their geological position, (2) their physical structure, and (3) their chemical composition.

GEOLOGICAL CLASSIFICATION.—The geological position of rocks has but little connection with their properties as building materia's. As a general rule, the more ancient rocks are the stronger and more durable; but to this there are many notable exceptions. According to the usual geological classification rocks are divided into three classes, viz.:

Igneous, of which greenstone (trap), basalt, and lava are examples.

Metamorphic, comprising granite, slate, marble, etc.

Sedimentary, represented by sandstones, limestones, and clay.

PHYSICAL CLASSIFICATION.—With respect to the structural character of their large masses, rocks are divided into two great classes: (1) the unstratified, (2) the stratified, according as they do or do not consist of flat layers.

The *unstratified* rocks are for the most part composed of an aggregation of crystalline grains firmly cemented together. Granite, trap, basalt, and lava are examples of this class. All the unstratified rocks are composed as it were of blocks which separate from each other when the rock decays or when struck violent blows. These natural joints are termed the *line of cleavage* or *rift*, and in all cutting or quarrying of unstratified rocks the work is much facilitated by taking advantage of them.

The *stratified* rocks consist of a series of parallel layers, evidently deposited from water, and originally horizontal, although in most cases they have become more or less inclined and curved by the action of disturbing forces. It is easier to divide

them at the planes of division between these layers than elsewhere. They are traversed by veins or cracks, sometimes empty, sometimes containing crystals, sometimes filled with "dikes," or masses of unstratified rock. These veins or dikes are often accompanied by a "fault" or abrupt alteration of the level of the strata. Besides its principal layers or strata, a mass of stratified rock is in general capable of division into thinner layers; and, although the surfaces of division of the thinner layers are often parallel to those of the strata, they are also often oblique or even perpendicular to them. This constitutes a *laminated* structure.

Laminated stones resist pressure more strongly in a direction perpendicular to their laminæ than parallel to them; they are more tenacious in a direction parallel to their laminæ than perpendicular to them; and they are more durable with the edges than with the sides of their laminæ exposed to the weather. Therefore in building they should be placed with their laminæ or "beds" perpendicular to the direction of greatest pressure, and with the edges of these laminæ at the face of the wall.

CHEMICAL CLASSIFICATION.—The stones used in building are divided into three classes, each distinguished by the predominant mineral which forms the chief constituent, viz.:

Silicious stones, of which granite, gneiss, and trap are examples.

Argillaceous stones, of which clay, slate, and porphyry are examples.

Calcareous stones, represented by limestones and marbles.

Requisites for Good Building Stone.

The requisites for good building stone are durability, strength, cheapness, and beauty.

DURABILITY—The durability of stone is a subject upon which there is very little reliable knowledge. The durability will depend upon the chemical composition, physical structure, and the position in which the stone is placed in the work. The same stone will vary greatly in its durability according to the nature and extent of the atmospheric influences to which it is subjected.

The sulphur acids, carbonic acid, hydrochloric acid, and traces of nitric acid, in the smoky air of cities and towns, and the carbonic acid in the atmosphere of the country ultimately decompose any stone of which either carbonate of lime or carbonate of magnesia forms a considerable part.

Wind has a considerable effect upon the durability of stone,

High winds blow sharp particles against the face of the stone and thus grind it away. Moreover, it forces the rain into the pores of the stone, and may thus cause a considerable depth to be subject to the effects of acids and frost.

In winter water penetrates porous stones, freezes, expands, and disintegrates the surface, leaving a fresh surface to be similarly acted upon.

STRENGTH is generally an indispensable attribute, especially under compression and cross-strain.

CHEAPNESS is influenced by the ease with which the stone can be quarried and worked into the various forms required. Cheapness is also affected by abundance, facility of transportation, and proximity to the place of use.

APPEARANCE.—The requirement of beauty is that it should have a pleasing appearance. For this purpose all varieties containing much iron should be rejected as they are liable to disfigurement from rust-stains caused by the oxidation of the iron under the influence of the atmosphere.

Tests for Stone.

The relative enduring qualities of different stones are usually ascertained by noting the weight of water they absorb in a given time. The best stones as a rule absorb the smallest amount of water.

To determine the absorptive power, dry a specimen and weigh it carefully, then immerse it in water for 24 hours and weigh again. The increase in weight will be the amount of absorption.

TABLE 1.

ABSORPTIVE POWER OF STONES.

	Percentage of Water absorbed.
Granites	0.06 to 0.15
Sandstones	0.41 " 5.48
Limestones	0.20 " 5.00
Marbles	0.08 " 0.16

EFFECT OF FROST (*Brard's Test*).—To ascertain the effect of frost, small pieces of the stone are immersed in a concentrated boiling solution of sulphate of soda (Glauber's salts), and then hung up for a few days in the air.

The salt crystallizes in the pores of the stone, sometimes forcing

off bits from the corners and arrises, and occasionally detaching larger fragments.

The stone is weighed before and after submitting it to the test. The difference of weight gives the amount detached by disintegration. The greater this is, the worse is the quality of the stone.

Effect of the Atmosphere (*Acid Test*).—Soaking a stone for several days in water containing 1 per cent of sulphuric and hydrochloric acids will afford an idea as to whether it will stand the atmosphere of a large city. If the stone contains any matter likely to be dissolved by the gases of the atmosphere, the water will be more or less cloudy or muddy.

A drop or two of acid on the surface of a stone will create an intense effervescence if there is a large proportion present of carbonate of lime or magnesia.

Preservation of Stone.

There are a great many preparations that have been used for the prevention of the decay of building stones, as paint, coal-tar, oil, beeswax, rosin, paraffine, soft-soap, soda, etc. All of the methods are expensive, and there is no evidence to show that they afford permanent protection to the stone.

Ransome's Process consists in coating the surface of the stone first with a solution of silicate of soda or potash, and then with a solution of chloride of calcium or barium. The chemical reaction produces insoluble silicate of lime and chloride of sodium, which washes out.

The surface of the stone to be coated is made thoroughly clean and dry, all decayed parts being cut out and replaced by good.

The silicate is diluted with from 1 to 3 parts of soft water until it is thin enough to be absorbed by the stone freely. The less water that is used the better, so long as the stone is thoroughly penetrated by the solution.

The solution is applied with an ordinary whitewash brush. After about a dozen brushings over, the silicate will be found to enter very slowly. When it ceases to go in, but remains on the surface glistening, although dry to the touch, it is a sign that the stone is sufficiently charged; the brushing on should stop just short of this appearance. No excess must on any account be allowed to remain on the face. After the silicate has become *perfectly dry* the solution of chloride of calcium is applied freely (but brushed on lightly, without making it froth) so as to be absorbed with the silicate into the structure of the stone.

Special care must be taken not to allow either of the solutions to be splashed upon windows or painted work, as the stains cannot be removed.

The brushes or jets used for the silicate must not be used for the chloride, or *vice versa*.

About four gallons of each solution is required for every hundred square yards of surface, but this will depend upon the porosity of the stone treated.

II. Description of Building Stones.

Silicious Stones.

Granite is an unstratified rock composed of silica or quartz, feldspar, and mica. In addition to these essential constituents one or more accessory minerals may be present; the more commonly occurring are hornblende, pyroxene, epidote, garnet, tourmaline, magnetite, pyrite, and graphite. The character of the rock is often determined by the presence of these accessory constituents in quantity.

Granite varies in texture from very fine and homogeneous to coarse porphyritic rocks in which the individual grains are an inch or more in length. The color is also dependent upon the minerals present; if the feldspar is the orthoclase (potash spar), it communicates a red color; the soda-spar produces gray. The mica also plays an important part in the modification of color; if it is the white muscovite, it produces no change, but if the black biotite mica be present, it modifies the color accordingly. Hornblende gives a dark mottled appearance; pyroxene also gives a dark appearance; epidote communicates a green color.

The durability of the granites is closely related to their mineralogical composition. The presence or absence of certain species influences the hardness and homogeneous nature of the stone. Although popularly regarded as the most durable stone, there are some notable exceptions. The quartzose varieties are brittle, the feldspathic are easily decomposed; feldspar in excess causes rapid decay and disintegration in consequence of the action of air and water on the potash which seems to be removed, and the residue falls into a white powder composed chiefly of silica and alumina. The micaceous varieties are easily laminated.

The durability and hardness of granites are greater the more

quartz and hornblende predominate, and the less the quantity of feldspar and mica, which are the more weak and perishable ingredients. Smallness and lustre in the crystals of feldspar indicate durability, largeness and dulness the reverse.

If the mica or feldspar contains an excess of lime, iron, or soda, the granite is liable to decay.

The quantity of iron either as the oxide or in combination with sulphur will affect the durability.

The iron can generally be seen with a good glass; and a very short exposure to air, especially if assisted in dry weather by sprinkling with water to which has been added 1 per cent of nitric acid, will reveal it.

The name "granite" as popularly used is not restricted to rock species of this name in geological nomenclature, but includes what are known as gneisses (foliated and bedded granites), syenite, gabbro, and other crystalline rocks whose uses are the same; in fact, the similar adaptability and use have brought these latter species into the class of granites. The name is also often improperly applied to the diabase and trap rocks.

The term "syenite" is usually restricted by modern petrographers to a rock which is an aggregate of orthoclase and hornblende; in other words, a granite in which the quartz has disappeared, while the mica has been superseded by hornblende.

GNEISS AND MICA-SLATE consist of the same materials as granite, but in a stratified form. They are found in the neighborhood of granite, in strata much inclined, bent, and distorted, and often form great mountain masses. Gneiss resembles granite in its appearance and properties, but is less strong and durable. Mica-slate is distinguished by containing little or no feldspar so that it consists chiefly of quartz and mica.

TRAP (GREENSTONE) AND BASALT.—These are unstratified metamorphic rocks, and consist of granular crystals of hornblende or augite with feldspar. In trap the grains are considerably finer than in granite; in basalt they are scarcely distinguishable. Trap breaks up into small blocks, basalt into regular prismatic columns. Both these rocks are very compact, hard, tough, and durable; being generally without cleavage or bedding they are exceedingly intractable under the hammer or chisel, and consequently their use in masonry is very limited.

The "Palisades" on the western shore of the Hudson River, opposite and above New York, are composed of trap rock, which

splits easily into small blocks much used for paving under the name of "Belgian block." Crushed trap rock is also extensively used for making macadam pavements.

SANDSTONES are stratified rocks consisting of grains of sand, that is, small crystals of quartz cemented together by silicious, ferruginous, calcareous, or argillaceous material. From the nature of the cementing material the rocks are variously designated as ferruginous, calcareous, etc.

The hardness, strength, and durability depend upon the nature of the cementing material; if it be one which decomposes readily, as in the argillaceous and calcareous varieties, the whole mass is soon reduced to sand. When composed of nearly pure silica and well cemented, sandstones are as resistant to weather as granite, and very much less affected by the action of fire. When quarried they are usually saturated with quarry-water (a weak solution of silica) and are very soft, but on exposure to the air (called "seasoning") they become harder by the precipitation of the soluble silica.

The COLOR of sandstone is determined by the cementing material. A stone composed exclusively of grains of quartz, without foreign matter, is snow-white. The various shades of red and yellow are produced by the iron oxides; the purple tints are due to oxide of manganese; the gray, blue, and green tints are produced by iron in the form of ferrous oxide, carbonate, or silicate; the brown color is produced by the hydrated oxide of iron.

Sandstones are in general porous and capable cf absorbing much water, but they are comparatively little injured by moisture, except when built with the layers set on edge, in which case the expansion of water in freezing between the layers makes them split or "scale" off from the face of the stone; when built on the natural bed any water which may penetrate between the edges of the layers has room readily to expand or escape.

When there is much lime in the cementing matter of the sandstone it decays rapidly in the atmosphere of the seacoast, and in that of towns where much coal is burned; in the former case the lime is dissolved by muriatic acid, in the latter by sulphuric acid. Crystals of sulphuret of iron are sometimes embedded in the stone, which, when exposed to air and moisture, decompose and cause disintegration. These crystals are easily recognized by their yellow or yellowish-gray color and metallic lustre.

On account of its easy working qualities it has been named

"freestone" by stone-cutters. A great variety of other names are applied, derived from the appearance of the stone and the uses to which it is put.

Argillaceous Stones.

SLATE.—CLAY-SLATE is a primary stratified rock of great hardness and density, with a laminated structure making in general a great angle with the planes of its stratification. It splits readily along planes called "planes of slaty cleavage." This facility of cleavage is one of the most valuable characteristics, as it enables masses to be split into slabs and plates of small thickness and great area.

The color of slates varies greatly; those most frequently met with are dark blue, bluish black, purple, gray, bluish gray, and green. Red and cream-colored slates are also occasionally found.

Some slates are marked with bands or patches of a different color; *e.g.*, dark purple slates often have large spots of light green upon them. These are generally considered not to injure the durability of the slate, but they lower its quality by spoiling its appearance.

Ribs or *veins* are dark marks running through some slates. They are always objectionable, but particularly when they run in the direction of the length of the slate, for it will be very liable to split along the vein. These veins and ribbons are frequently soft and of inferior quality to the slate proper. On exposure to the weather they effloresce and show signs of decomposition due to the sulphate of iron contained in them. Such slates should not be allowed in good work.

Calcareous Stones.

LIMESTONES are composed of carbonate of lime combined with various minerals. There are many varieties, which differ in color, composition, and value for engineering and building purposes. The several kinds are usually designated by the name of the principal combined minerals. Thus, if it contains much sand it is called *silicious limestone;* if the silica is very fine grained it is called *hornstone;* if the silica is distributed in nodules or flakes, either in seams or throughout the mass, it is *cherty* limestone; if it contains silica and clay in about

equal proportions it is *hydraulic* limestone; if clay alone is the principal ingredient it is *argillaceous* limestone; if iron is the principal impurity it is *ferruginous* limestone; if iron and clay exceed the lime it is *ironstone;* if the ironstone is decomposed and the iron hydrated it is *rottenstone;* if carbonate of magnesia forms one third or less it is *magnesian* limestone; if carbonate of magnesia forms more than one third it is *dolomitic* limestone.

GRANULAR LIMESTONE consists of carbonate of lime in grains, which are in general shells or fragments of shells, cemented together by some compound of lime, silica, and alumina, and often mixed with a greater or less quantity of sand. It is always more or less porous. It is found in various colors, especially white and light yellowish brown. In many cases it is so soft when first quarried that it can be cut with a knife, and hardens by exposure to the air. It is found in various strata, especially the oolitic formation.

COMPACT LIMESTONE consists of carbonate of lime, either pure, or mixed with sand and clay. It is generally devoid of crystalline structure, of a dull earthy appearance, and of a dark blue, gray, black, or mottled color. In some cases, however, it is crystalline and full of organic remains. It is then known as crystalline limestone.

MAGNESIAN AND DOLOMITIC LIMESTONES.—When the carbonate of magnesia is present in limestone to the amount of one third or less it is called magnesian limestone; when the carbonate of magnesia forms one third or more it is called dolomitic limestone. Both kinds are found in various conditions, from the compact crystalline to the porous granular condition. The durability depends mainly on the texture; when that is compact they are extremely durable. When sand is present in the magnesian variety the weathering qualities are greatly injured. Some varieties are peculiarly subject to the attacks of sulphuric acid, which forms a soluble sulphate of magnesia easily washed away.

MARBLE is the purest form of carbonate of lime (except stalactites), and is an earlier formation of limestone, with a pressure which retained the carbonic acid. The name marble is generally applied to any limestone which will take a good polish. Marbles exhibit great diversity of color and texture; they are chiefly used for ornamentation and interior decorations.

TABLE 2.

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF VARIOUS STONES.

Granites.

Localities.	Specific Gravity.	Average Weight. Pounds per Cubic Foot.	Resistance to Crushing. Pounds per Square Inch.
Min.	2.60	163	12,000
Max.	2.80	176	35,000
Kirtland Rocks, Conn.	2.66	166	35,000
Lord's Island, "			24,000
Mystic River, "	2.63	164	22,250
New Haven, "			9,750
Millstone Point, "	2.70	169	16,187
Milford, "			22,600
New London, "	2.66	166	12,500
Sharkey's Quarry, Me.	2.72	170	22,125
Hurricane Island, "	2.67	167	15,000
Fox Island (blue), "			14,875
Vinal Haven (gray), "			13,000 to 18,000
Huron Island, Mich.			20,650
Duluth (dark), Minn.			17,750
" (light), "			19,000
East St. Cloud, "			28,000
Quincy (dark), Mass.	2.66	166	19,500
" (light), "			14,750
Fall River (gray), "			15,937
Cape Ann, "			12,423 / 19,500
Port Deposit, Md.			19,750
Patapsco, "	2.64	163	5,340
Jersey City, N. J.	3.03	189	20,750
Passaic Co. (gray), N. J.			24,040
Chaumont Bay, N. Y.	2.65	162	23,700
Westchester Co., "	2.65	166	18,250
Garrison's (gray), "	2.58	161	13,370
Staten Island (blue), "	2.86	179	22,250
Keene (bluish gray), N. H.	2.65	166	12,875
Gunnison, Colo.			13,000
Platte Cañon (red), Colo.		164	14,600
Richmond, Va.	2.72 / 2.63	170 / 164	14,100 / 21,250
Westerly (gray), R. I.	2.67	167	14,937
Burnet Co., Tex.	2.82	176	11,891
Aberdeen, Scotland (gray)	2.62	163	10,900
" " (red)	2.62	165	10,760
Gneiss, Conn.	2.70	168	19,600
Syenite, Fourth Mountain, Ark.	2.64	167	30,740
Trap, Jersey City, N. J.	3.03	178 / 189	20,000 / 24,000
" Palisades, "			19,700
" Staten Island, N. Y.	2.86	178	22,250

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF VARIOUS STONES. (*Continued.*)

Sandstones.

Localities.	Specific Gravity.	Average Weight. Pounds per Cubic Foot.	Resistance to Crushing. Pounds per Square Inch.
Min.	2.23	137	5,000
Max.	2.75	170	18,000
Potsdam (red), N. Y.	2.60	162	42,804
Malden (bluestone), "	2.75	171	
Medina (pink), "	2.41	151	17,725
Warsaw (bluestone), "	2.68	167	
Albion (brown), "	2.42	151	13,500
Little Falls (brown), "	2.25	141	9,850
Oxford (bluestone), "	2.71	169	13,472
Haverstraw (red), "	2.13	133	4,350
Belleville (gray), N. J.	2.26	147	11,700
" (brown), "		148	13,310
Berea (drab), Ohio	2.57	160	7,250 10,250
Vermillion (drab), "	2.16	135	8,850
Massillon (yellow drab), "			8,750
Cleveland (olive-green), "	2.24	140	6,800
North Amherst, "			6,650
Seneca (red brown), "	2.14	134	5,000
Warrensburg (bluish drab), Mo.	2.39	149	9,687
Middletown (Portland), Conn.	2.36 2.62	147 163	6,950 13,000
Dorchester (brown), New Brunswick			9,150
Kasota (pink), Minn.	2.63	164	10,700
Frontenac (light buff), "	2.32	145	6,250
Fond du Lac, "			8,750
Fond du Lac (purple), Wis.	2.22	138	6,250
Marquette, Mich	2.53	158	7,450
Bristow, Va.	2.61	157	5,714
Long Meadow (reddish brown), Mass			7,000 14,000
Hummelstown, Pa			12,810
Manitou (light red), Colo.			6,000 11,000
St. Vrain, "			11,505
Fort Collins (gray), "		140	11,707
SLATE.			
Northampton Co., Pa		173	

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF VARIOUS STONES. (*Continued.*)

Limestones.

Localities.	Specific Gravity.	Average Weight. Pounds per Cubic Foot.	Resistance to Crushing. Pounds per Square Inch.
Min.	1 90	118	7,000
Max.	2.75	175	20,000
Glens Falls, N. Y.	2.70	169	11,475
North River, "	2.71	169	13,425
Lake Champlain, "	2.75	172	25,000
Canajoharie, "	2.68	168	20,700
Erie Co. (blue), "	2.64	165	12,250
Kingston, "	2.69	168	13,900
Garrison's, "	2.63	165	18,500
Joliet (white), Ill.	2 54	159	16,900
Grafton (magnesian), Ill.			17,000
Marblehead (white), Ohio.	2.40	150	12,600
Marquette (drab), Mich.	2.34	146	8,050
Lime Island (drab), "	2.50	156	{ 18,000 / 25,000 }
Billingsville, Mo.			7,250
Cooper Co. (dark drab), Mo.	2.32	141	6,650
Bardstown (dark), Ky.	2.69	168	16,250
Sturgeon Bay (bluish drab), Wis.	2.78	174	21,500
Bedford, Ind.			{ 6,000 / 10,000 }
Salem, "			8,625
Red Wing, Minn.			23,000
Stillwater, "			10,750
Avondale (gray), Pa.			18,000
" (light), "			12,112
Conshohocken "			{ 14,090 / 16,340 }

Marbles.

Min	2.62	165	8,000
Max.	2.95	179	20,000
East Chester, N. Y.	2.87	179	13,504
Hastings, "			18,941
Dorset, Vt.	2.63	165	7,612
Rutland, "			10,746
Mill Creek, Ill.	2.57	172	9,687
Montgomery (blue), Pa.			{ 9,590 / 13,700 }
North Bay, Wis.	2.80	175	20,025
Montgomery, Va.			8,950
Lee, Mass.			{ 20,504 / 22,700 }
Stockbridge, Mass.			10 382
Colton, Cal.			17,783
Italy.	2.69	168	13,425

Inspection of Stone.

The fitness of stone for structural purposes may be determined approximately by examining a fresh fracture, the appearance and characteristics of which are as follows:

The *even* fracture occurs when the surfaces of division are planes in definite positions, and indicates a crystalline structure.

The *uneven* fracture presents sharp projections, and is characteristic of a granular structure.

The *slaty* fracture occurs when the planes of division are parallel to the lamination and are uneven for other directions of division.

The *conchoidal* fracture presents smooth concave and convex surfaces, and is characteristic of a hard and compact structure.

The *earthy* fracture leaves a rough dull surface, and indicates softness and brittleness.

Stones which contain "drys," i.e., seams containing material not thoroughly cemented together, or "crowfoots" i.e., veins containing dark-colored uncemented material, should be rejected.

To test the soundness of any stone, strike it smart blows with a light hammer on both beds; if it rings clearly, it is sound; if the sound is dull, it is seamy and should be rejected.

Stones to be used for face work should be closely examined for seams, the effect of which is to allow rain-water to penetrate to the interior of the stone and, under the action of frost, to split and crack it.

THE DEFECTS OF GRANITE are termed *knots*, *sap*, *shakes*, and *rot*. *Knots* are lumps of different color from the main body; they are usually black or white. *Sap* is the name given to discolorations or stains. *Shakes* are seams which usually have discolored edges. *Rot* is the name given to stone which crumbles easily.

SANDSTONES AND LIMESTONES must be closely examined for *seams*, *holes*, and *cavities* filled with sand, clay, or uncemented material.

The appearance of good sandstone is characterized by the sharpness of the grains, smallness of the cementing material, and a clear shining, translucent appearance on a newly broken surface. Rounded grains and a dull mealy surface indicate soft and perishable stone.

Quarrying.

In quarrying stone for building purposes there should be as little blasting as possible, as it shakes the stone. Stone showing powder-cracks should be rejected.

Weather-worn stone and stone from the outcrop or capping of a quarry should not be used in good work. Stone should if possible be worked at once after being quarried, for it is then easier to cut.

The quarrying of limestone, marble, and sandstone during winter is not advisable, as they are liable to be injured by the freezing of the contained water.

Seasoning.

Stones of a porous nature which contain water when quarried are said to be *green* or *sappy*. Such stones must be exposed to the drying action of the air before using them, otherwise they will be split and fractured by the action of frost upon the contained water.

III. Artificial Stones.

Brick.

Brick is an artificial stone made by submitting clay, which has been suitably prepared and moulded into shape, to a temperature of sufficient intensity to convert it into a semi-vitrified state.

The quality of the brick depends upon the kind of clay used and upon the care bestowed on its preparation.

The clays of which brick is made are chemical compounds consisting of silicates of alumina, either alone or combined with other substances, such as iron, lime, soda, potash, magnesia, etc., all of which influence the character and quality of the brick, according as one or the other of those substances predominates.

Iron gives hardness and strength; hence the red brick of the Eastern States is often of better quality than the white and yellow brick made in the West. *Silicate of lime* renders the clay too fusible and causes the bricks to soften and to become distorted in the process of burning. *Carbonate of lime* is at high temperatures changed into caustic lime, renders the clay fusible, and when exposed to the action of the weather absorbs moisture, promotes disintegration, and prevents the adherence of the mortar. *Magnesia* exerts but little influence on the quality; in small quantities it renders the clay fusible; at 60° Fahr. its crystals lose their water of crystallization, and cold water decomposes them, forming an insoluble hydrate in the form of a white powder. In air-dried brick this action causes cracking. The *alkalies* are found in small quantities in the best of clays; their presence tends to promote softening, and this goes on the more rapidly if it has been burned at too low a temperature. *Sand* mixed with the clay in moderate quantity (one part of sand to four of clay is about the best proportion) is beneficial, as tending to prevent excessive shrinking in the fire. Excess of sand destroys the cohesion and renders the brick brittle and weak.

Manufacture of Brick.

The manufacture of brick may be classified under the following heads:

Excavation of the clay, either by manual or mechanical power.

Preparation of the clay consists in (*a*) removing stones and mechanical impurities; (*b*) tempering and moulding, which is now

done almost wholly by machinery. There is a great variety of machines for tempering and moulding the clay, which, however, may be grouped into three classes, according to the condition of the clay when moulded: (1) soft-mud machines, for which the clay is reduced to a soft mud by adding about one quarter of its volume of water; (2) stiff-mud machines, for which the clay is reduced to a stiff mud; (3) dry-clay machines, with which the dry or nearly dry clay is forced into the moulds by a heavy pressure without having been reduced to a plastic mass. These machines may also be divided into two classes, according to the method of filling the moulds: (1) those in which a continuous stream of clay is forced from the pug-mill through a die and is afterwards cut up into bricks; and (2) those in which the clay is forced into moulds moving under the nozzle of the pug-mill.

Drying and Burning.—The bricks, having been dried in the open air or in a drying-house, are burned in kilns; the time of burning varies with the character of the clay, the form and size of the kiln, and the kind of fuel, from six to fifteen days.

Color of Bricks.

The color of bricks depends upon the composition of the clay, the moulding sand, temperature of burning, and volume of air admitted to the kiln. Pure clay free of iron will burn *white*, and mixing of chalk with the clay will produce a like effect. Iron produces a tint ranging from *red* and *orange* to *light yellow*, according to the proportion of the iron.

A large proportion of oxide of iron mixed with pure clay will produce a *bright red*, and where there is from 8 to 10 per cent, and the brick is exposed to an intense heat, the oxide fuses and produces a *dark blue* or *purple*, and with a small volume of manganese and an increased proportion of the oxide the color is darkened even to a *black*.

A small volume of lime and iron produces a *cream color*, an increase of iron produces *red*, and an increase of lime *brown*.

Magnesia in presence of iron produces *yellow*.

Clay containing alkalies and burned at a high temperature produces a *bluish green*.

Classification of Brick.

Bricks are classified according to (1) the way in which they are moulded; (2) their position in the kiln while being burned; and (3) their form or use.

I. The method of moulding gives rise to the following terms:

SOFT-MUD BRICK.—One moulded from clay which has been reduced to a soft mud by adding water. It may be either hand-moulded or machine-moulded.

STIFF-MUD BRICK.—One moulded from clay in the condition of stiff mud. It is always machine-moulded.

PRESSED BRICK.—One moulded from dry or semi-dry clay.

RE-PRESSED BRICK.—A soft-mud brick which, after being partially dried, has been subjected to an enormous pressure. It is also called, but less appropriately, pressed brick. The object of the re-pressing is to render the form more regular and to increase the strength and density.

SLOP BRICK.—In moulding brick by hand, the moulds are sometimes dipped into water just before being filled with clay, to prevent the mud from sticking to them. Brick moulded by this process is known as slop brick. It is deficient in color and has a comparatively smooth surface, with rounded edges and corners. This kind of brick is now seldom made.

SANDED BRICK.—Ordinarily, in making soft-mud brick, sand is sprinkled into the moulds to prevent the clay from sticking; the brick is then called sanded brick. The sand *on the surface* is of no advantage or disadvantage. In hand-moulding, when sand is used for this purpose, it is certain to become mixed with the clay and occur in streaks in the finished brick, which is very undesirable.

MACHINE-MADE BRICK.—Brick is frequently described as "machine-made"; but this is very indefinite, since all grades and kinds are made by machinery.

II. When brick was generally burned in the old-style up-draught kiln, the classification according to position was important; but with the new styles of kilns and improved methods of burning, the quality is so nearly uniform throughout the kiln that the classification is less important. Three grades of brick are taken from the old-style kiln:

ARCH OR CLINKER BRICKS.—Those which form the tops and sides of the arches in which the fire is built. Being overburned and partially vitrified, they are hard, brittle, and weak.

BODY, CHERRY, OR HARD BRICKS.—Those taken from the interior of the pile. The best bricks in the kiln.

SALMON, PALE, OR SOFT BRICKS.—Those which form the exterior of the mass. Being underburned, they are too soft for ordinary work, unless it be for filling. The terms *salmon* and *pale*

refer to the color of the brick, and hence are not applicable to a brick made of a clay that does not burn red. Although nearly all brick-clays burn red, yet the localities where the contrary is true are sufficiently numerous to make it desirable to use a different term in designating the *quality*. There is not necessarily any relation between color, and strength and density. Brick-makers naturally have a prejudice against the term *soft brick*, which doubtless explains the nearly universal prevalence of the less appropriate term salmon.

III. The form or use of bricks gives rise to the following classification:

COMPASS BRICK.—Those having one edge shorter than the other. Used in lining shafts, etc.

FEATHER-EDGE BRICK.—Those of which one edge is thinner than the other. Used in arches ; and more properly, but less frequently, called *voussoir* brick.

FRONT OR FACE BRICK.—Those which, owing to uniformity of size and color, are suitable for the face of the walls of buildings. Sometimes face bricks are simply the best ordinary brick ; but generally the term is applied only to re-pressed or pressed brick made especially for this purpose. They are a little larger than ordinary bricks.

SEWER BRICK.—Ordinary hard brick, smooth, and regular in form.

KILN-RUN BRICK.—All the brick that are set in the kiln when burned.

HARD KILN-RUN BRICK.—Brick burned hard enough for the face of outside walls, but taken from the kiln unselected.

RANK OF BRICKS.

In *regularity of form* re-pressed brick ranks first, dry-clay brick next, then stiff-mud brick, and soft-mud brick last. Regularity of form depends largely upon the method of burning.

The *compactness and uniformity* of texture, which greatly influence the durability of brick, depend mainly upon the method of moulding. As a general rule, hand-moulded bricks are best in this respect, since the clay in them is more uniformly tempered before being moulded; but this advantage is partially neutralized by the presence of sand-seams. Machine-moulded soft-mud bricks rank next in compactness and uniformity of texture. Then come machine-moulded stiff-mud bricks, which vary greatly in durability with the kind of machine used in their manufacture. By

some of the machines the brick is moulded in layers (parallel to any face, according to the kind of machine) which are not thoroughly cemented, and which separate under the action of frost. The dry-clay brick comes last. However, the relative value of the products made by different processes varies with the nature of the clay used.

Glazed and Enamelled Bricks.

Glazed Bricks.—Bricks are glazed by means of a composition of porcelain or glass which fuses and renders the surface vitreous. This may be done by applying a flux or a chemical solution to the surface. Pigments of metallic oxides are added to the composition, which give it any desired color or shade. The coloring is done either under the glaze or in the glaze. When the application is to be made under the glaze it is customary to dip the bricks previously burned into a "slip" of colored clay composed, in most instances, of one part colored glass, ground, and two parts clay, the latter causing adhesion of the slip; the brick is then fired, or, after being allowed to dry, is coated with a transparent glaze and then fired. When the color is to be applied in the glaze the brick is dipped into a transparent colored glaze made of silicious sand, salt, and oxide of lead combined with the required coloring pigment. The composition is prepared by pulverization to a homogeneous mass, then calcined, pulverized again, and made applicable by dissolving in water to the consistency of cream. The faces of the brick to be glazed are dipped in this solution or are coated with it by brushes, after which the brick is subjected to a temperature sufficient to fuse the glaze on the surface.

Enamelled Bricks are generally made of a particular quality of clay, containing a considerable proportion of fire clay. The enamel may either be applied to the unburnt brick or to the brick after it is burnt. In burning the enamel fuses and unites with the body of the brick, but does not become transparent, and therefore shows its own color. It is claimed that an enamelled brick is more durable than a glazed brick, and will not so readily chip or peel. The enamel is also the purest white.

An enamelled surface may be distinguished from a glazed surface by chipping off a piece of the brick. The glazed brick will show the layer of slip between the glaze and the brick; the enamelled brick will show no line of demarcation between the body of the brick and the enamel.

TABLE 3.

SIZE AND WEIGHT OF BRICKS.

The variations in the dimensions of brick render a table of exact dimensions impracticable.

As an exponent, however, of the ranges of their dimensions, the following averages are given:

Baltimore front	$8\frac{1}{4}'' \times 4\frac{1}{8}'' \times 2\frac{3}{8}''$
Wilmington "	(same)
Washington "	(same)
Croton "	$8\frac{1}{2}'' \times 4'' \times 2\frac{1}{4}''$
Maine ordinary	$7\frac{1}{2}'' \times 3\frac{3}{8}'' \times 2\frac{3}{8}''$
Milwaukee "	$8\frac{1}{2}'' \times 4\frac{1}{8}'' \times 2\frac{3}{8}''$
North River, N. Y.	$8'' \times 3\frac{1}{2}'' \times 2\frac{1}{4}''$
English	$9'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$

The Standard Size as adopted by the National Brickmakers' Association and the National Traders and Builders' Association is for common brick $8\frac{1}{4} \times 4 \times 2\frac{1}{4}$ inches, and for face brick $8\frac{3}{8} \times 4\frac{1}{8} \times 2\frac{1}{4}$ inches.

Re-pressed Brick weighs about 150 lbs. per cubic foot, common brick 125, inferior soft 100. Common bricks will average about $4\frac{1}{2}$ lbs. each.

Hollow Brick, used for interior walls and furring, are usually of the following dimensions:

Single, 8 in. long, $3\frac{5}{8}$ in. wide, $2\frac{1}{4}$ in. thick.
Double, 8 " " $7\frac{1}{2}$ " " $4\frac{1}{2}$ " "
Treble, 8 " " $7\frac{1}{4}$ " " $7\frac{1}{4}$ " "

Roman Brick, 12 in. long, 4 to $4\frac{1}{2}$ in. wide, $1\frac{1}{2}$ in. thick.

TABLE 4.

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF BRICK.

Designation of Brick.	Specific Gravity.	Weight per Cubic Foot. Pounds.	Resistance to Crushing. Pounds per Square Inch.
Best pressed..	2.4	150	5,000 to 14,978
Common hard............	1.6 to 2.0	125	5,000 to 8,000
Soft...........	1.4	100	450 to 600

Inspection of Brick.

The characteristics of good brick are :

1. *Soundness ;* that is, freedom from cracks and flaws.

2. *Hardness*, to enable it to withstand pressure and strain.

3. *Regularity of shape and size ;* it should have plane faces, parallel sides, and sharp right-angled edges.

4. Should show when broken a compact uniform structure, hard and somewhat glassy, and free from air-bubbles, cracks, cavities, and lumps.

5. Should emit a clear ringing sound when struck a sharp blow.

6. Should not absorb more than about $\frac{1}{10}$ of its weight of water.

7. The specific gravity should be 2 or more.

8. The crushing strength of a half brick, when ground flat and pressed between thick metal plates, should be at least 7000 lbs. per square inch.

9. The modulus of rupture should be at least 1000 lbs. per square inch.

Good bricks are generally of a dark reddish-brown color, and sometimes show vitrified spots on the surface; it is not well, however, to depend upon this fact, for it is only an indication of the amount of heat to which the brick has been subjected, while the clay of which the brick is made may be impure and ill prepared.

Bad bricks are generally recognized by their reddish-yellow color, but still more by the dull sound which they emit when struck. Their grain being soft they crumble easily and absorb water with avidity.

All brick intended for building that does not take up a small percentage of water is too much burned, and the mortar will adhere to it imperfectly.

When a brick left in water either scales or swells, it is of bad quality and contains caustic lime.

A brick which being made red hot and then having water poured over it does not crack is of excellent quality.

The strength of building brick, both transverse and crushing, varies in tolerably close inverse ratio with the quantity of water absorbed in 24 hours. The strongest bricks absorb least water.

Good building brick absorb from 6 to 12 per cent of water in 24 hours, and with no greater absorption than 12 per cent will ordinarily show from 7000 to 10,000 or more pounds per square inch of ultimate crushing strength, and a transverse modulus of 700 to 1200 lbs. or more.

Poor building brick will absorb from $\frac{1}{7}$ to $\frac{1}{4}$ of their weight of water in 24 hours, and average a little more than half the transverse and crushing strength of good brick.

An immersed brick is nearly saturated in the first hour of immersion ; in the remaining 24 hours the absorption is only 0.5 to 0.8 per cent of its weight, as a rule.

The strength of bricks in the kiln is least in the top courses, and increases quite rapidly for the first 10 or 12 courses and afterwards more slowly down to the arch bricks.

Bricks made by the dry process are, as a rule, notably less porous and stronger than those made by the wet-mud process. To this rule, however, there are some exceptions.

EFFECT OF FROST.—To ascertain if bricks will withstand the action of frost, boil one for half an hour in a solution of sulphate of soda, allow to remain in the solution until cold, then suspend it by a string over the vessel in which it has been boiled. In 24 hours the surface of the brick will be covered with small crystals; the brick is then to be immersed in the solution until the crystals disappear, and again suspended. Repeat this operation for five days. If after this treatment a number of particles of brick are found at the bottom of the vessel, the bricks are incapable of resisting the effects of frost.

Fire-brick.

Fire-brick is used wherever high temperatures are to be resisted. They are made from fire-clay by processes very similar to those adopted in making ordinary brick.

Fire-clay may be defined as native combinations of hydrated silicates of alumina, mechanically associated with silica and alumina in various states of subdivision, and sufficiently free from silicates of the alkalies and from iron and lime to resist vitrification at high temperatures. The presence of oxide of iron is very injurious; and, as a rule, the presence of 6 per cent justifies the rejection of the brick. The presence of 3 per cent of combined lime, soda, potash, and magnesia should be a cause for rejection. The sulphide of iron—pyrites—is even worse than the substances first named.

A good fire-clay should contain from 52 to 80 per cent of silica and 18 to 35 per cent of alumina and have an uniform texture, a somewhat greasy feel, and be free from any of the alkaline earths.

Good fire-brick should be uniform in size, regular in shape, homogeneous in texture and composition, easily cut, strong, and infusible.

A properly burnt fire-brick is of an uniform color throughout its mass. A dark central patch and concentric rings of various shades of color is due mainly to the different states of oxidation of the iron and partly to the presence of unconsumed carbonaceous matter, and indicates that the brick was burned too rapidly.

Fire-brick are made in various forms to suit the required work. A straight brick measures 9 × 4½ × 2½ inches and weighs about 7 lbs., or 120 lbs. per cubic foot; specific gravity 1.93. One cubic foot of wall requires 17 9-inch bricks; one cubic yard requires 460. One ton of fire-clay should be sufficient to lay 3000 ordinary bricks.

English fire-bricks measure 9 × 4½ × 2½ inches.

To secure the best results fire-brick should be laid in the same clay from which they are manufactured. It should be used as a thin paste, and not as mortar: the thinner the joint the better the furnace wall. The brick should be dipped in water as they are used, so that when laid they will not absorb the water from the clay paste. They should then receive a thin coating of the prepared fire-clay, and be carefully placed in position with as little of the fire-clay as possible.

Terra-cotta.

Terra-cotta is largely used as a substitute for stone in the ornamental part of buildings. It is composed of mixed clays, to which sometimes is added a large proportion of ground glass, pottery, and sand. After being properly kneaded it is forced into moulds smeared with soft soap; it is then carefully dried, and gradually baked in a pottery-kiln, and then slowly cooled.

When properly prepared and burnt it is not affected by the atmosphere or acid fumes.

Terra-cotta is subject to unequal shrinkage in baking, which sometimes causes the pieces to be twisted. When this is the case great care must be taken in laying the blocks; otherwise the long lines of a building, such as those of string-courses or cornices, which are intended to be straight, are apt to be uneven, and the faces of the blocks are often in *winding*.

Twisted and warped blocks are sometimes set right by chiselling, but this should be avoided, for if the vitrified skin on the surface

be removed the material will not be able to withstand the attacks of the atmosphere, etc.

Terra-cotta is made in several colors, depending chiefly upon the amount of heat it has gone through. White, pale gray, pale yellow or straw color indicate a want of firing. Rich yellow, pink, and red varieties are generally well burned. A green hue is a sign of absorption of moisture and of bad material.

Inferior terra-cotta is sometimes made by overlaying a coarsely prepared body with a thin coating of a finer and more expensive clay Unless these bodies have been most carefully tested and assimilated in their contraction and expansion, they will in the course of time destroy one another; that is, the inequality in their shrinkage will cause hair-cracks in the outer skin, which will retain moisture, and cause the surface layer to fall off in scales after winter frosts.

Another very reprehensible custom is that of coating over the clay, just before it goes into the kiln, with a thin film of some ochreish paint mixed with a finely ground clay, which produces a sort of artificial bloom which speedily wears off after exposure to the action of the atmosphere.

Terra-cotta, whether plain or ornamental, is generally made of hollow blocks formed with webs inside, so as to give extra strength and keep it true while drying. This is necessitated because good, well-burned terra-cotta cannot safely be made of more than about 1¼ inches in thickness, whereas when required to bond with brickwork it must be at least four inches thick. When extra strength is needed these hollow spaces are filled with concrete or brickwork, which greatly increases the crushing strength of the terra-cotta, although alone it is able to bear a very heavy weight. A solid block of terra-cotta of one foot cube has borne a crushing strain of 500 tons and over.

TABLE 5.

RESISTANCE TO CRUSHING OF TERRA-COTTA.

	Tons per Cubic Foot
Solid block	523
Hollow block (unfilled)	186
" " (slightly made and unfilled)	80
Solid " 2-inch square, red	492
" " " " buff	449
" " " " gray	369

The safe working strength of unfilled blocks may be taken at 5 tons per square foot, and for blocks filled solid with concrete or brickwork at 10 tons per square foot.

The weight of terra-cotta in solid blocks is 122 pounds per cubic foot; the weight of hollow blocks $1\frac{1}{2}$ inches thick varies from 65 to 85 pounds per cubic foot. Porous terra-cotta roofing 3 inches thick weighs 16 pounds per square foot, and 2 inches thick 12 pounds.

POROUS TERRA-COTTA is made of a mixture of clay and some combustible material, such as sawdust, charcoal, cut straw, etc. When baked the combustible material is consumed, leaving the terra-cotta full of small holes. It is fireproof, of light weight, great tenacity, strong, can be cut with edge-tools, will hold nails driven in, and gives a good surface for plastering.

Tiles.

COMMON TILES are made of the same materials as bricks; they are used for paving and roofing.

ENCAUSTIC TILES are those in which the colors are produced by substances mixed with the clay.

PAVING TILES are of many shapes and sizes, and about one inch thick.

ROOFING TILES are of many forms and sections, such as plain, corrugated, Venetian, ridge, etc.

FLAT TILES $6\frac{1}{4}'' \times 10\frac{1}{2}'' \times \frac{5}{8}''$ weigh from 15 to 18 lbs. per square foot of roof, the lap being one half the length of the tile. Tiles with grooves and fillets weigh from 7 to 9 lbs. per square foot of roof.

PAN TILES $14\frac{1}{2}'' \times 10\frac{1}{2}''$ laid $10''$ to the weather weigh about 8 lbs. per square foot.

Inspection of Tiles.

The inspection and testing of tiles should embrace:

1. Examination of dimension, appearance, and soundness.
2. Weight and specific gravity.
3. The real and apparent absorption of water.
4. Presence of constituents soluble in water.
5. Strength.

Stones made by Patented Processes.

Several kinds of artificial stone are manufactured under patented processes. They are all a combination of hydraulic cement, sand, pebbles, stone-dust, etc., with or without the addition of some indurating material, as baryte, litharge, etc. They are manufactured either in *place* or in form of blocks at a factory. Such stones are extensively employed in architecture and for the paving of cellars, areas, footpaths, etc.

IV. Cementing Materials.

The cementing materials employed in building are produced by the calcination of calcareous minerals. As these minerals differ greatly in their composition, ranging from pure carbonate of lime to stones containing variable proportions of silica, alumina, magnesia, oxide of iron, manganese, etc., they confer different properties upon the calcined product, which render necessary certain precautions in its manipulation and treatment, and furnishes a basis of classification, as follows:

1st. Common or fat limes.

2d. Poor or meagre limes.

3d. Hydraulic limes.

4th. Hydraulic cements, which may be divided into three classes, viz.: Portland, Rosendale, and Pozzuolana. The first two differ from the third in that the ingredients of which the former are composed must be roasted before they acquire the property of hardening under water, while the ingredients of the latter need only be pulverized and mixed with water to a paste.

The hydraulic cements do not slake after calcination, differing materially in this particular from the limes proper. They can be formed into paste with water, without any sensible increase in volume, and little, if any, disengagement of heat, except in certain instances among those varieties which contain the maximum amount of lime. They do not shrink in hardening, like the mortar of rich lime, and can be used with or without the addition of sand, although for the sake of economy sand is combined with them. The hydraulic activity of some of them is so energetic as to set under water at 65° F. in three or four minutes, although others require as many hours.

Limes.

Rich Limes.—The common fat or rich limes are those obtained by calcining pure or very nearly pure carbonate of lime. In slaking they augment to from two to three and a half times that of the original mass. They will not harden under water, or even in damp places excluded from contact with the air. In the air they harden by the gradual formation of carbonate of lime, due to the absorption of carbonic acid gas.

The pastes of fat lime shrink in hardening to such a degree that they cannot be employed for mortar without a large dose of sand.

POOR LIMES.—The poor or meagre limes generally contain silica, alumina, magnesia, oxide of iron, sometimes oxide of manganese, and in some cases traces of the alkalies, in relative proportions, which vary considerably in different localities. In slaking they proceed sluggishly, as compared with the rich limes —the action only commences after an interval of from a few minutes to more than an hour after they are wetted; less water is required for the process, and it is attended with less heat and increase of volume than in the case of fat limes.

HYDRAULIC LIMES.—The hydraulic limes, including the three subdivisions of limes, viz., *slightly hydraulic*, *hydraulic*, and *eminently hydraulic*, are those containing after calcination sufficient of such foreign constituents as combine chemically with lime and water to confer an appreciable power of setting or hardening under water without the access of air. They slake still slower than the meagre limes, and with but a small augmentation of volume, rarely exceeding 30 per cent of the original bulk.

Inspection of Lime.

QUALITY.—The quality of good lime is indicated by the perfectness with which the lumps fall to powder when water is applied. No mashing of the lumps or stirring should be necessary, though the slaking will be somewhat hastened by so doing.

Freshly burned lime may be known by its being in hard lumps rather than in powder or easily crumbled lumps.

PRESERVATION.—Lime, on account of its affinity for moisture, and, when moist, for carbonic acid, absorbs them gradually from the atmosphere, and returns somewhat to the state of carbonate of lime; this process is termed "air-slaking" and weakens the setting quality of the lime. To protect it from this deteriorating action it should be packed in close casks and stored in a dry place until required for use, and then quickly used; therefore the best lime for use is that which has been recently burned.

Lime, when thoroughly slaked and mixed into a paste, may be kept for an indefinite time in that condition without deterioration if protected from contact with the air so that it will not dry up. It is customary to keep the lime paste in casks, or in the wide shallow boxes in which it was slaked, or heaped up on the ground,

covered over with the sand to be subsequently incorporated with it in making the mortar.

SLAKING.—Slaking is the process of chemical combination of quicklime with water ; one equivalent of water combines with one equivalent of lime, and forms *slaked lime*, or, in chemical language, *hydrate of lime*.

The process of slaking is a simple one. The lime is spread out in a suitable bed and as much water as it will readily absorb is poured upon it. This moistening with water gives rise to various phenomena : the lime almost immediately cracks, swells, and falls into a bulky powder with a hissing, crackling sound, slight explosions, and considerable evolution of heat and steam ; the volume is increased from two to three and a half times the original bulk, the variation depending both upon the density of the original carbonate and the manner of conducting the process.

The same process takes place slowly by absorption of moisture from the atmosphere ; the lime falls into powder with increase of volume, but without perceptible heating. Lime slaked in this way is said to be *air-slaked*. Some carbonic acid gas is also absorbed and a part of the lime returns to the state of a carbonate of lime.

Air-slaked lime is deficient in setting properties and should not be used for building purposes.

The common limes contain impurities which prevent a thorough, uniform, and prompt slaking of the entire mass ; hence the necessity of slaking some days before the lime is required for use, to avoid all danger to the masonry by subsequent enlargement of volume and change of condition.

The slaking of lime, although an exceedingly simple operation, is liable to be unskilfully performed by the workmen. They are apt either to use too much water, which reduces the slaked lime to a semi-fluid condition and thereby injures its binding qualities ; or, not having used enough water in the first place, seek to remedy the error by adding more after the slaking has well progressed and a portion of the lime is already reduced to powder, thus suddenly depressing the temperature and chilling the lime, which renders it granular and lumpy. The lime should not be stirred while slaking. The essential point is to secure the reduction of all the lumps.

The best mode of slaking, so far as regards the quality of the mortar, is by sprinkling the loose lump lime with about one fourth to one third by trial of its own bulk of water, and then covering

it with a layer of sand or with a tarpaulin ; this retains the heat and accelerates the slaking. All the lime necessary for any required quantity of mortar should be slaked at least one day before it is incorporated with the sand.

Memoranda and Definitions of Lime.

Lime is shipped either in bulk or in barrels. If in bulk, it is impossible to preserve it for any considerable length of time.

A barrel of lime usually weighs about 230 lbs. net, and will make about three tenths of a cubic yard of stiff paste. A bushel weighs 75 lbs.

PURE LIME is a protoxide of calcium, or, in other words, a metallic oxide. It has a specific gravity of 2.3, is amorphous, somewhat spongy, highly caustic, quite infusible. possesses great affinity for water, and if brought in contact with it will rapidly absorb 22 to 23 per cent of its weight, passing into the condition of hydrate of lime.

SLAKED LIME is hydrate of lime.

QUICKLIME, or caustic lime, is the resulting lime left from the calcination of limestone—it is chemically known as calcium oxide.

LIMESTONE.—Carbonate of lime.

CRYSTALLIZED LIME.—Marble.

FOSSIL LIME.—Chalk.

SULPHATE OF LIME.—Gypsum.

CALCINATION is heating to redness in air.

SLAKING is the process of chemical combination of quicklime with water.

AIR-SLAKING.—Hydration by the absorption of moisture from the atmosphere.

Portland Cement.

Portland cement is produced by burning, with a heat of sufficient intensity and duration to induce incipient vitrification, certain argillaceous limestones, or calcareous clays, or an artificial mixture of carbonate of lime and clay, and then reducing the burnt material to powder by grinding. Fully 95 per cent of the Portland cement produced is artificial. The name is derived from the resemblance which hardened mortar made of it bears to a stone found in the isle of Portland, off the south coast of England.

The quality of Portland cement depends upon the quality of the raw materials, their proportion in the mixture, the degree to which the mixture is burnt, the fineness to which it is ground, and the constant and scientific supervision of all the details of manufacture.

Characteristics of Portland Cement.

Color.—The color should be a dull bluish or greenish gray, caused by the dark ferruginous lime and the intensely green manganese salts. Any variation from this color indicates the presence of some impurity : blue indicates an excess of lime ; dark green, a large percentage of iron ; brown, an excess of clay ; a yellowish shade indicates an underburned material.

Fineness.—It should have a clear almost floury feel in the hand; a gritty feel denotes coarse grinding.

Weight.—It should weigh from 84 to 88 pounds per cubic foot. A cement weighing from 70 to 80 pounds per cubic foot is invariably a weak one, though it may be of the requisite fineness ; at the same time a heavy cement if coarsely ground is also weak and will have no carrying capacity for sand. Light weight may be caused by laudable fine grinding or by objectionable underburning. In testing, weight and fineness must be taken in conjunction.

Specific Gravity is between 3 and 3.05. As a rule the strength of Portland cement increases with its specific gravity.

Tensile Strength.—When moulded neat into a briquette and placed in water for seven days it should be capable of resisting a tensile strain of from 300 to 500 pounds per square inch.

Setting.—A pat made with the minimum amount of water should set in not less than three hours, nor take more than six hours.

Expansion and Contraction.—Pats left in the air or placed in water should during or after setting show neither expansion nor contraction, either by the appearance of cracks or change of form,

A cement that possesses the foregoing properties may be considered a fair sample of Portland cement and would be suitable for any class of work.

OVERLIMED CEMENT is likely to gain strength very rapidly in the beginning and later to lose its strength, or if the percentage of free lime be sufficient it will ultimately disintegrate.

BLOWING or SWELLING of Portland cement is caused by too much lime or insufficient burning. It also takes place when the cement is very fresh and has not had time to cool.

ADULTERATION.—Portland cement is adulterated with slag cement and slaked lime. This adulteration may be distinguished by the light specific gravity of the cement, and by the color, which is of a mauve tint in powder, while the inside of a water-pat when broken is deep indigo. Gypsum or sulphate of lime is also used as an adulterant.

Natural Cement.

The *Rosendale* or *natural* cements are produced by burning in draw-kilns at a heat just sufficient in intensity and duration to expel the carbonic acid from argillaceous or silicious limestones containing less than 77 per cent of carbonate of lime, or argillo-magnesian limestone containing less than 77 per cent of both carbonates, and then grinding the calcined product to a fine powder between millstones.

The natural cements usually take the name of the place of manufacture. The name *Rosendale* is derived from the place (Rosendale, Ulster Co., N. Y.) where it was first made.

CHARACTERISTICS OF ROSENDALE CEMENTS.

The natural cements have a porous, globular texture. They do not heat up nor swell sensibly when mixed with water. They set quickly in air, but harden slowly under water, without shrinking, and attain great strength with well-developed adhesive force.

COLOR.—Usually brown, of greater or less intensity. The color gives no clue to the cementitious value, since it is due chiefly to oxides of iron and manganese, which bear no direct relation to the cementing properties. A very light color generally indicates an inferior underburned cement. A Rosendale cement made at Coplay, Pa., from the same stone as Portland is a light gray in color.

SETTING.—A pat made with the minimum amount of water should set in about 30 minutes.

FINENESS.—At least 93 per cent must pass through a No. 50 sieve.

WEIGHT.—Varies from 49 to 56 pounds per cubic foot.

SPECIFIC GRAVITY about 2.70.

TENSILE STRENGTH.—Neat cement one day, from 40 to 80 pounds. Seven days, from 60 to 100 pounds. One year, from 300 to 400 pounds.

Inspection of Cement.

The quality or constructive value of a cement is generally ascertained by submitting a sample of the particular cement to a series of tests. The properties usually examined are the *color*, *weight*, *activity*, *soundness*, *fineness*, and *tensile strength*. Chemical analysis is sometimes made, and specific gravity test is substituted for that of weight. Tests of compression and adhesion are also sometimes added. As these tests cannot be made upon the site of the work, it is usual to sample each lot of cement as it is delivered and send the samples to a testing laboratory.

SAMPLING CEMENT.—The cement is sampled by taking a small quantity (1 to 2 lbs.) from the centre of the package. The number of packages sampled in any given lot of cement will depend upon the character of the work, and varies from every package to 1 in 5 or 1 in 10. When the cement is brought in barrels the sample is obtained by boring with an auger either in the head or centre of the barrel, drawing out a sample, then closing the hole with a piece of tin firmly tacked over it. For drawing out the sample a brass tube sufficiently long to reach the bottom of the barrel is used. This is thrust into the barrel, turned around, pulled out, and the core of cement knocked out into the sample-can, which is usually a tin box with a tightly fitting cover.

Each sample should be labelled, stating the number of the sample, the number of bags or barrels it represents, the brand of the cement, the purpose for which it is to be used, the date of delivery, and date of sampling.

FORM OF LABEL.

Sample No......................................
No. of Barrels..................................
Brand..
To be used......................................
Delivered................ 18.. *Sampled*........ 18..
By................

The sample should be sent at once to the testing office, and none of the cement should be used until the report of the tests is received.

The testing of cement ordinarily consumes 30 days. Therefore the supply must be so gauged that a sufficient quantity will be kept on hand to allow the tests to be made without delay to the work of construction.

After the report of the tests is received the rejected packages should be conspicuously marked with a "C" and should be removed without delay; otherwise it is liable to be used.

Rough Tests for Cement.—As one lot of cement is liable to differ very much from another lot of the same brand, it is very necessary that the inspector apply some rough tests to get an idea of how the cement is running.

TEST FOR SETTING.—Make a small pat of neat cement and note the interval of time that elapses until it resists penetration under a light pressure of the thumb-nail.

TEST FOR EXPANSION.—Make a small pat of neat cement and when set in air place it under water, where it should remain for a few days. If the cement be good the pat will show no alteration in form, but if any cracks show on the edges, or other deviations from the original shape of the pat, they indicate that the cement is of an expansive nature, and therefore not to be trusted. But because a cement will not stand this test it is not in all cases to be condemned as useless, as its expansive or blowing property may be attributable to its being used too soon after leaving the mill. A proper process of cooling—placing it in a thin layer on a dry floor for a short time—may correct the defect.

TEST FOR SOUNDNESS.—Place some mortar of neat cement in a glass tube (a milled lamp-chimney is excellent for this purpose) and pour water on top. If the tube breaks the cement is unfit for use in damp places.

CONTRACTION due to the cement being overclayed may be detected by a similar test to that for expansion.

BALL TEST.—This test is extensively employed by masons. Take enough neat cement to make a ball an inch in diameter, mix with just sufficient water to make it mould readily, and roll it into a ball. Allow it to set in air for about two hours, then place under water, and allow it to remain from 1 to 10 days. It should become gradually harder, and show no signs of cracking or crumbling. Any cement that does not endure this test is not of sufficiently good quality to make satisfactory work.

Preservation of Cements.—Cements require to be stored in a dry place protected from the weather; the packages should not be placed directly on the ground, but on boards raised a few inches from it. If necessary to stack it out of doors a platform of planks should first be made and the pile covered with canvas. Portland cement exposed to the atmosphere will absorb moisture until it is practically ruined. The absorption of moisture by the natural cements will cause the development of carbonate of lime, which will interfere with the subsequent hydration.

Cements—Memoranda and Definitions.

Cement is shipped in barrels or in cotton or paper bags.

The usual dimensions of a barrel are: length 2 ft. 4 in., middle diameter 1 ft. 4⅛ in., end diameter 1 ft. 3⅛ in.

The bags hold 50, 100, or 200 pounds.

A barrel weighs about as follows:

Rosendale, N. Y.	300	lbs. net
" Western	265	"
Portland	375	"

A barrel of Rosendale cement contains about 3.40 cubic feet and will make from 3.70 to 3.75 cubic feet of stiff paste, or 79 to 83 pounds will make about one cubic foot of paste. A barrel of Rosendale cement (300 lbs.) and two barrels of sand (7½ cubic feet) mixed with about half a barrel of water will make about 8 cubic feet of mortar, sufficient for

192	square feet of mortar-joint	½ inch thick
288	" " " "	⅜ " "
384	" " " "	¼ " "
768	" " " "	⅛ " "

A barrel of Portland cement contains about 3.25 to 3.35 cubic feet—100 pounds will make about one cubic foot of stiff paste.

A barrel of cement measured loosely increases considerably in bulk. The following results were obtained by measuring in quantities of two cubic feet:

1 bbl. Norton's Rosendale gave	4.37	cu. ft.
" Anchor Portland "	3.65	"
" Sphinx " "	3.71	"
" Buckeye " "	4.25	"

The weight of cement per cubic foot is as follows.

Portland, English and German	77 to 90	lbs.
" fine-ground French	69	"
" American	92 " 95	"
Rosendale	49 " 56	"
Roman	54	"

A bushel contains 1.244 cubic feet. The weight of a bushel can be obtained sufficiently close by adding 25% to the weight per cubic foot.

ACTIVITY denotes the speed with which a cement begins to *set*. Cements differ widely in their rate and manner of *setting*. Some occupy but a few minutes in the operation, and others require several. Some begin setting immediately and take considerable time to complete the set, while others stand for a considerable time with no apparent action and then set very quickly. The point at which the set is supposed to begin is *when the stiffening of the mass first becomes perceptible*, and the end of the set is when cohesion extends through the mass sufficiently to offer such resistance to any change of form as to cause rupture before any deformation can take place.

FINENESS.—The cementing and economic value of a cement is affected by the degree of fineness to which it is ground. Coarse particles in a cement have no setting power and act as an adulterant. In a mortar or concrete composed of a certain quantity of inert material bound together by a cementing material it is evident that to secure a strong mortar or concrete it is essential that each piece of aggregate shall be entirely surrounded by the cementing material, so that no two pieces are in actual contact. Obviously, then, the finer a cement the greater surface will a given weight cover, and the more economy will there be in its use.

The proper degree of fineness is reached when it becomes cheaper to use more cement in proportion to the aggregate than to pay the extra cost of additional grinding.

The fineness of a cement is determined by measuring the percentage which will not pass through sieves of a certain number of meshes per square inch. Three sieves are generally used, viz.:

No. 50,	2,500	meshes	per	square	inch
" 74,	5,476	"	"	"	"
" 100,	10,000	"	"	"	"

The usual degree of fineness required is that the residue left on a No. 50 sieve shall not be more than 10 per cent by weight.

FREEZING OF CEMENT MORTARS.—Portland cement mortar suffers no surface disintegration under any condition of freezing, but the strength is impaired, in a majority of cases, and sometimes as much as 40 per cent.

Rosendale cement is disintegrated upon the surface when exposed to frost while setting, the amount of injury depending to a certain extent upon the number of degrees of the exposure below the freezing-point.

The cohesion of Rosendale cement mortar may be entirely destroyed by immersion in water, which becomes frozen around it.

In some cases Rosendale cement shows an increase of strength acquired under the conditions which it passes through while frozen.

Portland cement is injured relatively less by freezing as the ratio of cement to sand decreases.

Salt used in the mixing water, in proportions varying around 1 to 15, assists Rosendale cement to resist the disintegrating action of frost, but appears to have an injurious effect on the strength. The injury to Portland cement is decreased with about the same proportion of salt.

HYDRAULICITY.—Lime or cement is said to be more or less hydraulic according to the extent to which paste or mortar made from it will set under water, or in positions where it is excluded from the action of the air.

HYDRAULIC ACTIVITY is the term used to denote the quickness or time required for a mortar to attain a small degree of strength.

HYDRAULIC ENERGY OR STRENGTH is the term applied to the ultimate strength attained by a mortar. There is no necessary relation between time of setting and ultimate strength; but, as a general rule, the slow-setting cements ultimately attain to a greater strength than quick-seting ones.

QUICK AND SLOW SETTING.—The aluminous natural cements are commonly "quick setting," though not always so, as those containing a considerable percentage of sulphuric acid may set quite slowly. The magnesian and Portland varieties may be either "quick" or "slow." Specimens of either variety may be had that will set at any rate, from the slowest to the most rapid, and no distinction can be drawn between the various classes in this regard.

Water containing sulphate of lime in solution retards the set-

ting. This fact has been made use of in the adulteration of cement, powdered gypsum being mixed with it to make it slow-setting, greatly to the injury of the material.

The temperature of the water used affects the time required for setting: the higher the temperature, within certain limits, the more rapid the *set*. Many cements which require several hours to set when mixed with water at a temperature of 40° F. will set in a few minutes if the temperature of the water be increased to 80° F. Below a certain inferior limit, ordinarily from 30° to 40° F., the cement will not set, while at a certain upper limit, in many cements between 100° and 140° F., a change is suddenly made from a very rapid to a very slow rate, which then continually decreases as the temperature increases, until practically the cement will not set.

The quick-setting cements usually set so that experimental samples can be handled within 5 to 30 minutes after mixing. The slow-setting cements require from 1 to 8 hours. Freshly ground cements set quicker than older ones.

STRENGTH.—The strength of a cement mortar is usually determined by submitting a specimen of known cross-section to a tensile strain. The reason for adopting tensile tests is that comparatively light strains produce rupture; and that, since mortar is less strong in tension than in compression, in most cases of failure of mortar it is broken by tensile stress, even though the masonry be under compression.

Table 6 shows the average minimum and maximum tensile strength per square inch which some good cements have attained.

SETTING denotes the process of combination amongst the particles of the cement under the action of water.

SOUNDNESS denotes the property of not expanding or contracting or cracking or checking in setting. These effects may be due to free lime, free magnesia, or to unknown causes. Testing soundness is, therefore, determining whether the cement contains any *active* impurity. An inert adulteration or impurity affects only its economic value; but an active impurity affects also its strength and durability.

TABLE 6.

TENSILE STRENGTH OF CEMENT MORTAR.

Age of Mortar when Tested.	Average Tensile Strength in Pounds per Square Inch.			
	Portland.		Rosendale.	
	Min.	Max.	Min.	Max.
CLEAR CEMENT.				
One hour, or until set, in air, the remainder of the time in water:				
1 *day*	100	140	40	80
One day in air, the remainder of the time in water:				
1 *week*	250	550	60	[illegible]
4 *weeks*	350	700	100	[illegible]
1 *year*	450	800	300	[illegible]
1 PART CEMENT TO 1 PART SAND.				
One day in air, the remainder of the time in water:				
1 *week*	....	....	30	50
4 *weeks*	....	....	50	80
1 *year*	....	....	200	300
1 PART CEMENT TO 3 PARTS SAND.				
One day in air, the remainder of the time in water:				
1 *week*	80	125	....	....
4 *weeks*	100	200	....	....
1 *year*	200	350	....	....

Miscellaneous Cements.

SLAG CEMENTS are those formed by an admixture of slaked lime with ground blast-furnace slag. The slag used has approximately the composition of an hydraulic cement, being composed mainly of silica and alumina, and lacking a proper proportion of lime to render it active as a cement. In preparing the cement the slag upon coming from the furnace is plunged into water and reduced to a spongy form from which it may be readily ground. This is dried and ground to a fine powder. The powdered slag and slaked lime are then mixed in proper proportions and ground together, so as to very thoroughly distribute them through the mixture. It is of the first importance in a slag cement that the slag be very finely ground, and that the ingredients be very uniformly and intimately incorporated.

Both the composition and methods of manufacture of slag cements vary considerably in different places. They usually contain a higher percentage of alumina than Portland cements, and

the materials are in a different state of combination, as, being mixed after the burning, the silicates and aluminates of lime formed during the burning of Portland cement cannot exist in slag cement.

The tests for slag cement are that briquettes made of one part of cement and three parts of sand by weight shall stand a tensile strain of 140 pounds per square inch (one day in air and six in water), and must show continually increasing strength after seven days, one month, etc. At least 90 per cent must pass a sieve containing 40,000 meshes to the square inch, and must stand the boiling test.

POZZUOLANAS are cements made by a mixture of volcanic ashes with lime, although the name is sometimes applied to mixed cements in general. The use of pozzuolana in Europe dates back to the time of the Romans.

ROMAN CEMENT is a natural cement manufactured from the septaria nodules of the London Clay formation; it is quick-setting, but deteriorates by age and exposure to the air.

LAFARGE CEMENT.—This is a patented cement similar to Portland, but, unlike Portland or the natural cements, does not stain marble, limestone, or other porous stones when used in setting them. For this reason it is largely used in setting and backing up the stone-work in fine buildings.

Asphaltum.

BITUMEN,* ASPHALTUM, ASPHALT.—*Bitumen* is the name used to denote a group of mineral substances, composed of different hydrocarbons, found widely diffused throughout the world in a variety of forms which grade from thin volatile liquids to thick semi-fluids and solids, sometimes in a free or pure state, but more frequently intermixed with or saturating different kinds of inorganic or organic matter.

To designate the condition under which bitumen is found different names are employed; thus the liquid varieties are known as *naphtha* and *petroleum*, the semi-fluid or viscous as *maltha* or *mineral tar*, and the solid or compact as *asphaltum* or *asphalt*.

Three distinct varieties of asphaltum are recognized, namely, the *earthy*, the *elastic*, and the *hard* or *compact*.

The *earthy* variety, represented by the *chapopota* of Mexico, Colombia, and other parts of South America, has a brownish-

black dull color, an earthy uneven fracture, when freshly excavated a strong though not unpleasant earthy odor, is soft enough to take an impression of the nail, hardens slightly on exposure to the atmosphere, and burns with a clear brisk flame, emitting a powerful odor, and depositing much soot.

Elastic asphaltum is of various shades of brown; is soft, flexible, and elastic ; it has an odor strongly bituminous, and is of about the density of water ; it burns with a clear flame and much smoke. Like caoutchouc, it takes up pencil-marks, and on this account is called *mineral caoutchouc ;* it has been found only at three places : in the fissures of a slaty clay at Castleton, England ; at Montrelais, France ; and in Massachusetts.

Hard or *compact asphaltum* is the most useful variety ; it forms large deposits in many parts of the world, and is of various degrees of quality, according to its age and the impurities mixed with it ; when nearly pure its ordinary characteristics are as follows : Color brownish black and black ; lustre resinous or coal-like ; opaque. At temperatures below 100° F. it is brittle and breaks with a conchoidal fracture. Melts ordinarily at 190° F. to 195° F., and is liquid at about 212° F. At 212° F. it has a peculiar but agreeable aromatic odor, somewhat resembling, but still very different from, that of coal-tar ; at ordinary temperatures the odor is scarcely perceptible, but when rubbed it is quite strong. It kindles readily and burns brightly with a thick smoke. Distilled by itself it yields a bituminous oil of a yellow color (consisting of hydrocarbons mixed with oxidized matter), water, some combustible gases, and sometimes traces of ammonia.

After combustion it leaves about one third of its weight of charcoal and ashes containing silica, alumina, oxide of iron, sometimes oxide of manganese, lime, and other inorganic and organic matter. Its composition and hardness are variable.

Specific Gravity.—Pure bitumen has a density less than water ; but in consequence of the impurities mixed with it the specific gravity of asphaltum varies from 1.0 to 1.7. *Solubility:* It is insoluble in water, partly or wholly soluble in chloroform and disulphide of carbon, partly or wholly in oil of turpentine and petroleum ether, and commonly partly in alcohol.

By different solvents asphaltum may be decomposed into three distinct though complex substances which have been named by Boussingault and other chemists who have investigated it *petrolene*, *asphaltene*, and *retine.* Nothing definite is known concerning these compounds or how their variable proportions and

composition affect the quality of asphaltum. In the past they have received but little attention from chemists, due probably to the limited use of asphaltum ; but now, in view of its large and increasing employment for paving and other industrial purposes, their investigation offers a wide and undoubtedly profitable field for chemical research.

The characteristics of these compounds, so far as known, are generally as follows :

Petrolene is the compound which is considered to give the viscous or adhesive quality. It may be described as that portion of the bitumen which is soluble in petroleum ether. It is lighter than water, very combustible, and has a high boiling-point, pale-yellow color, and peculiar odor. On evaporating off the ether it remains as a resin with a brownish-black color, which dissolves readily in the volatile oils. Its composition is carbon, hydrogen, and sulphur. The amount present in an asphaltum is variable, ranging from 3 to 70 per cent of the weight of the asphaltum.

Asphaltene is the compound which gives the hardness to asphaltum. It contains the elements of petrolene, together with a quantity of oxygen, and probably arises from the oxidation of that compound. It is that portion of the bitumen which is insoluble in ether. It is dissolved out by carbon disulphide, chloroform, benzene, etc. Its color is a brilliant black ; density greater than water. It burns like resins in general, leaving a very abundant coke. Like petrolene, it is composed of carbon, hydrogen, and oxygen, and the amount present in an asphaltum is as variable—ranging from 1 to about 60 per cent.

Retine is dissolved out by alcohol (anhydrous) from that portion of the asphaltum which is unaffected by the solvents above mentioned. It is a yellow resin composed of carbon, hydrogen, and sulphur. What effect this compound has upon asphaltum is unknown. Some authorities claim that its presence is injurious.

ORIGIN OF BITUMEN.—The origin of bitumen is unknown. It is supposed to be the ultimate product resulting from the destruction under certain conditions of the organized remains of animals and vegetables, producing (1) naphtha, (2) petroleum, (3) maltha or mineral tar, (4) asphaltum. The whole of these substances merge into each other by insensible degrees, so it that is impossible to say at what point maltha ends and asphaltum begins. *Naphtha*, the first of the series, is in some localities found flowing out of the earth as a clear, limpid, and colorless liquid ; as such it is a mixture of hydrocarbons, some of which are very vol-

atile and evaporate on exposure. It takes up oxygen from the air, becomes brown and thick, and in this condition it is called *petroleum*.

The hardening of the bituminous fluids which have oozed out or been exposed by other causes upon the surface of the earth seems, in most cases at least, to have resulted from the loss of the vaporizable portions, and also from a process of oxidation which consists, first, in a loss of hydrogen, and finally in the oxygenation or evaporation of the more volatile portions, which gradually transforms them into mineral tar or maltha, and, still later, into solid glossy asphaltum, of which *gilsonite*, *wurtzilite*, *uintahite*, etc., are examples.

Occurrence and Distribution of Asphaltum.—Deposits of asphaltum are found widely diffused throughout the world, and at various altitudes ranging from below sea-level to thousands of feet above. It is, however, seldom found among the primitive or older rock formations, but seems to belong exclusively to the secondary and tertiary formations. Intermixed with the argillaceous stratas it forms extensive beds or lake-like deposits on both continents, the most remarkable of which are those situated in the West Indies and South America. The most notable of these are the so-called pitch lakes on the island of Trini dad, and at Bermudez, Venezuela.

Saturating the calcareous and sandstone formations, it forms large subterraneous deposits in Europe and the United States. The calcareous varieties occur more extensively in Europe than in America, and are the source of the material employod there for street-paving under the name of *asphalte*. The sandstone class is found extensively in the Western and Southwestern States, especially in California, Texas, Kentucky, and the Indian Territory.

In a free or nearly pure state it is found in veins and seams in the primitive rock and volcanic formations. This class of deposit is rare, and the amount of asphaltum is generally insignificant. A notable exception, however, are the deposits of Utah, etc The mines from which gilsonite, wurtzilite, uintahite are produced are said to be very extensive, and the material is very nearly pure Similar deposits are found in Mexico, Cuba, and various parts of South America.

In many localities beds of shale, sand, and cretaceous limestone are found saturated with maltha, from which the bitumen is extracted by boiling or macerating with water.

From the variety of the deposits and their manner of occurrence it seems that asphaltum belongs to no particular era or age. Moreover, the asphaltum obtained from these different sources is not uniform either in character, appearance, hardness, or chemical composition. The ultimate composition of specimens from several localities is given in the following table:

COMPOSITION OF ASPHALTUM.

Locality.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
Trinidad, W. I.	80.32 to 85.89	6.30 to 11.06	0.56 to 1.40	... ... to 0.50	2.49 to 11.48	....
Cuba, "	82.34	9.10	6.25	1.91	....	0.40
Caxatambo, Peru	88.66	9.69	1.65		....	....
N. S. (albertite)	86.04	8.96	1.97	2.93	trace	0.10
W. Va (grahamite) ...	76.45	7.83	13.14	....	....	2.26
Auvergne, France....	77.64	7.86	8.35	1.02	......	5.13
Oklahoma, I. T.......	55.00	10.21	7.14	2.74	....	24.91 and silicates
Mexico	80.34	10.09	9.57	....	....	....
Utah (gilsonite)	80.88	9.76	6.05	3.30	....	0.01

NOMENCLATURE.—As indicated above, the varieties of bitumen and asphaltum are as numerous as the localities producing them; hence there is a great variety of names used to designate the same substance, which is oftentimes misleading, if not confusing. As an illustration of this variety the following may be mentioned: native pitch, mineral pitch, glance pitch, grahamite, albertite, piauzite, elaterite, gilsonite, wurtzilite, uintahite, turrellite, etc.

Sometimes the name of the locality where it is found is used as a prefix, and is thus useful to indicate the source. Such names are Dead Sea bitumen, Egyptian asphalt, Cuban, Trinidad, Bermuda, Californian, Kentucky, etc.

The name *asphalté* has been adopted by the French to designate the material obtained from their bituminous limestone deposits, and is now generally employed throughout Europe to denote both the carbonate of lime impregnated with asphaltum and the pavement made from that material.

The name *lithocarbon* has been adopted to designate a cretaceous limestone saturated with bitumen found in Texas.

Some authorities apply the terms asphaltum, asphalt, and liquid asphalt to the semi-fluid and viscous bituminous substance, or *maltha*, which by heat may be transformed into asphaltum. This

application seems to be erroneous, because asphaltum technically means bitumen in the solid form. Others use the same terms to designate the entire mixture of bitumen, mineral and organic matter, while others apply them to denote the purified material.

The names which seem to be the most used in the United States, and which are at the same time descriptive of the various classes, are as follows:

Crude asphaltum or *crude asphalt* is applied to all mixtures of bitumen, clay, sand, etc.; e. g., crude Trinidad asphalt.

Refined asphaltum or *asphalt* is used to denote the asphaltum after it has been wholly or partly freed from the combined organic and inorganic matters.

The limestone rocks impregnated with bitumen are called *bituminous* or *asphaltic limestones.* The term *rock asphalt* is also applied to the same material, the name of the source being also used, as "Italian rock asphalt," "Val de Travers rock asphalt," etc.

The sandstones containing bitumen are known as *bituminous* or *asphaltic sandstones,* the name of the source being also mentioned.

The semi-fluid bitumen is designated by the names *maltha* and *mineral tar.*

The term *asphalt* is also frequently but erroneously applied to various preparations in which the cementing material is coal-tar or the residue of oil-refineries, etc.—substances which are entirely dissimilar to asphaltum, though apparently possessing some of its characteristics.

The term *bitumen* is employed to designate the truly bituminous portion of the asphaltum and its compounds.

Refined Asphaltum is asphaltum freed from the combined water and accompanying inorganic and organic matter. By comparatively simple operations the several varieties of asphaltum may be reduced to an equal state of purity.

The argillaceous varieties, such as Trinidad, Bermudez, etc., are purified in iron vessels by the application of heat either directly from fire or indirectly by steam; the temperature employed ranges from 212° F. to 350° F. During the application of the heat the asphaltum is liquefied, the combined water is evaporated, the organic matters rise to the surface and are skimmed off, and the inorganic settle to the bottom of the vessel; when the liberation of the impurities is complcted the liquid asphaltum is drawn off into barrels, and constitutes the refined asphaltum of commerce.

The calcareous and silicious varieties are purified by boiling or

macerating them with hot water, according to the freedom with which they part with the intermixed impurities. During the action of the water the sand and other ingredients fall to the bottom of the vessel, and the bitumen rises to the surface or forms clots on the sides of the boiler, whence it is skimmed off and thrown into another boiler, where it is boiled for some time, during which the water and more volatile oils are evaporated, and the mineral matters still retained fall to the bottom, leaving the bitumen in the form of a thick viscid substance, in which state it is used in several of the arts. By continuing the boiling for a considerable time or by increasing the temperature to about 250° F. the volatile portions are driven off, and the viscid bitumen is brought to a condition which upon cooling causes it to become solid.

The operation of refining or purifying, while exceedingly simple, requires to be performed with much care, for the reason that if the asphaltum is melted at too high a temperature it will be burned or coked, or if the heating is prolonged at a low temperature the result will be practically the same. In either case the petrolene is converted into asphaltene.

Asphaltic Cement.—Asphaltum in a refined or pure state is valueless as a cementing medium, owing to its hardness, brittleness, and lack of cementitious properties; therefore it is necessary to add some substance which will impart to it the required plastic, adhesive, and tenacious qualities. This substance must be one that will partially dissolve the asphaltene and form a chemical union by solution instead of a mechanical mixture. The duty which it has to perform is an important and peculiar one: if it is a perfect solvent of the constituents of the bitumen the adhesive qualities will be destroyed; if it is an imperfect one the asphaltum will retain its brittleness.

The requirements of a suitable flux are that it shall be a fluid containing no substances volatile under 300° F., and shall possess the power to dissolve the asphaltum without destroying or lessening its adhesive properties.

The materials employed to give the required qualities to the hard asphaltum are called the "flux," and those in general use are crude or specially prepared residuum oil obtained from the distillation of petroleum, and crude or refined maltha.

The process of adding the flux is called "oiling" or "tempering," and is conducted as follows: The refined asphaltum is melted and the temperature raised to about 300° F.; the oil

previously heated is then pumped or in other ways added to the asphaltum, in the proportion of 10 to 20 pounds of oil to 100 pounds of refined asphaltum; the proportion of the oil is varied between the limits stated according to its quality, the hardness of the asphaltum, and the purpose for which the cement is to be employed. The mixture of residuum oil and asphaltum is agitated either by mechanical means or by a blast of air for several hours or until the material has acquired the desired properties. The agitation must be performed with great thoroughness to secure a uniform mixture, and must be continued whenever the material is in a melted condition, as a certain amount of separation takes place when the melted cement stands at rest. It is therefore customary to agitate it constantly when in use as well as during its preparation.

The process of "tempering" when *maltha* is used as the flux is practically the same as outlined above, with the exception that the mixing is performed at a lower temperature and entirely by mechanical means, and a separation of the ingredients seldom occurs when the cement is standing at rest.

The maltha from many localities is to be had in the market; it is sold for fluxing purposes under various trade names, among which may be named "Alcatraz" liquid asphaltum, "Standard" liquid asphalt, "Utah" liquid asphalt, etc.; also artificial fluxing materials which are offered as substitutes for oil and maltha, such as the "Pittsburg," asphaltic flux etc. The analyses of some of these fluxing agents are as follows:

"ALCATRAZ" LIQUID ASPHALT.

Specific gravity	1.05	
Bitumen soluble in carbon disulphide	98.70	per cent
Bitumen soluble in petroleum naphtha	89.17	" "
Mineral matter	1.30	" "
Organic non-bituminous matter	trace	

"UTAH" LIQUID ASPHALT (CRUDE).

Specific gravity	0.9068	
Bitumen soluble in carbon disulphide	76 15	per cent
Bitumen soluble in ether	64.90	" "
Mineral matter	3.40	" "
Organic non-bituminous matter	20.45	" "
Loss at 100° C.	24.72	" "

"PITTSBURG" ASPHALTIC FLUX.

Moisture	0.05	per cent
Volatile oil 212° F. to 312° F.	1.60	" "
Volatile oil about 312° F.	89.19	" "
Fixed carbon	8.48	" "
Ash	0.68	" "
Bitumen soluble in carbon disulphide	99.32	" "
Bitumen soluble in ether	65.00	" "

The enduring qualities of an asphaltic cement depend upon (1) the character of the fluxing agent, (2) the temperature at which the asphaltum has been refined, and the temperature at which the flux is added, (3) the degree of incorporation of the flux with the asphaltum, that is, whether the union is a chemical or mechanical one.

Residuum Oil is a thick heavy oil varying considerably in composition, according to the source of the petroleum and method of distillation; its base is *paraffine*—a substance so different from asphaltum that when the two are brought together the result is a mixture partly mechanical and partly chemical, and, being of different specific gravities, they partly separate when allowed to stand for any considerable period without stirring.

In preparing the oil the object aimed at is (1) the removal of the hard paraffines, which are very susceptible to changes of temperature, becoming soft under the summer sun and brittle at or below the freezing-point; their presence imparts similar properties to the asphalt cement; (2) to remove the lighter and more volatile oils; care in their removal must be exercised: if too large a percentage is removed the oil becomes heavy and thick, and too large a proportion is required to make a cement of suitable consistency—therefore there is a limit to the amount that can be removed.

The oil is carefully examined to ascertain:

1. Specific gravity.
2. Flash-point.
3. Percentage volatile in a given time at 400° F.
4 Susceptibility to changes of temperature as revealed by changes in viscosity.
5. Presence of crystals of paraffine.

The specifications of Washington, D. C., provide that the heavy petroleum oil used in the manufacture of asphalt cement shall have the following characteristics;

It shall be a petroleum from which the lighter oils have been removed by distillation without cracking.

Specific gravity Baumé 17° to 21°. Flash-point not less than 300° F. Distillate at 400° F. for ten hours less than 10 per cent.

Shall not cease to flow above 60° F. Shall not require more than 21 pounds of oil for each 100 pounds of refined asphalt to produce the specific quality of cement.

The flash-point shall be taken in a New York State closed oil-tester. The distillate shall be made with about 90 grams of oil in a small glass retort provided with a thermometer and packed entirely in asbestos.

The flowing-point shall be determined by cooling 100 cc. of oil in a small bottle and noting the temperature at which it flows readily from one end of the bottle to the other.

Analysis and Tests of Asphaltum.—The tests employed to determine the relative merits of asphaltum and asphaltic cements comprise both chemical and physical investigations.

The chemical examination of the crude material involves the following determinations:

Specific gravity.
Percentage of moisture.
" " matter soluble in turpentine.
" " " " " carbon bisulphide.
" " " " " alcohol.
" " " " " ether.
" " " volatile in 10 hours at 400° F.
" " sulphuretted hydrogen evolved at 400° F.
" " non-bituminous organic matter.
" " mineral constituents.

Softening-point.
Flowing-point.

The examination of the physical properties (mechanical tests) involves the following determinations:

1. The refining of the crude material and making of an asphaltic cement.

2. Determining the penetrability of the cement.

3. Making a paving mixture and testing it for tensile and crushing strength.

The penetration tests are usually conducted in a machine invented by Prof. Bowen. This machine consists of a lever about 17 inches long, having the fulcrum at one end and a cambric

needle inserted in the other end, above which is placed a weight of 100 grams. The end near the needle is connected by a steel rod and waxed cord with a spindle having a long hand which moves about a dial divided into 360 degrees. Another cord and weight upon an enlarged part of the spindle keeps the first-mentioned cord taut. By a suitably contrived spring clip the steel rod can be released for any length of time, and the needle, which has first been brought to coincide with the surface of the asphalt cement placed under it in a tin box, allowed to penetrate under the action of the weight into the cement. The number of degrees through which the hand moves on the dial records the penetration of the cement; the length of time for which the needle is released is one second. Originally Prof. Bowen selected 77° F. as the proper temperature at which the test should be made, and brought the cement and machine to this degree by keeping them in a room warmed to this point. But as it is sometimes inconvenient or impossible to have a room temperature of 77°, other temperatures may be made available by placing the tin sample-box of asphalt cement in water at 77° and allowing it to acquire that temperature, when the test can be made as before, certain allowance being made to reduce the result to the normal temperature of 77° F.

The physical tests are performed in the usual machines employed for testing other cements.

As asphalt cement possesses the same qualities and can be used for the same purposes as hydraulic and other cements, its physical qualities can be tested in a similar manner; but the tests which have been made and published have been conducted without any regard to uniformity and under widely different conditions; therefore they are of little or no value in determining the relative merits of the cements.

Test for Bituminous Rock.—A specimen of the rock, freed from all extraneous matter, having been pulverized as finely as possible, should be dissolved in sulphurate of carbon, turpentine, ether, or benzine, placed in a glass vessel and stirred with a glass rod. A dark solution will result, from which will be precipitated the limestone. The solution of bitumen should then be poured off. The dissolvent speedily evaporates, leaving the constituent parts of the bitumen, each of which should be weighed so as to determine the exact proportion. The bitumen should be heated in a lead bath and tested with a porcelain or Baumé thermometer to 428 degrees Fahr. There will be little loss by evaporation if

the bitumen is good, but if bituminous oil is present the loss will be considerable. Gritted mastic should be heated to 450 degrees Fahr. The limestone should be next examined. If the powder is white and soft to the touch it is a good component part of asphalt; but if rough and dirty on being tested with reagents it will be found to contain iron pyrites, silicates, clay, etc. Some bituminous rocks are of a spongy or hygrometrical nature; thus, as an analysis which merely gives so much bitumen and so much limestone may mislead, it is necessary to know the quality of the limestone and of the bitumen.

The European bituminous limestone appears like a fine-grained rock, friable in summer, hard in winter. When heated to 50 or 60 degrees centigrade it can be crushed between the fingers, and if exposed for several hours to a fierce sun it crumbles into unctuous brown powder. Examined under the microscope it is found to consist of minute calcareous grains, each covered with a thin film of bitumen, which causes them to adhere together. If a small portion is heated the cementing bitumen is melted and releases the solid particles from a loose heap of a deep chocolate color. If this powder is raised to 175 or 212 degrees Fahr. and rapidly compressed in a mould it will regain, in cooling, its original consistency in the new form. And the process may be indefinitely repeated, no change being produced by melting, followed by compression and cooling.

V. TIMBER.

Structure of Timber.

Woods suitable for structural purposes are usually called timber, and are almost exclusively obtained from trees that grow by the formation of layers of wood over the external surface, and therefore called *exogenous*. There are a few exceptions, as the trees of the palm family, the bamboo, etc., which belong to the *endogenous* class.

When a tree is cut across it is seen that it is composed of three parts:

1st. The *bark*, having a thickness of from $\frac{1}{4}$ to $1\frac{1}{2}$ inches or more. This has no value for structural purposes, though useful in other respects; it hastens the decay of the tree after felling, and should always be removed. 2d. The *sap-wood*, which lies next the bark, having a thickness varying from $\frac{1}{2}$ to 4 inches; it is indicated by a lighter color, by being softer and less compact than the inner portion. 3d. The central portion surrounded by the sap-wood and called the *heart*. The boundary between the sap-wood and the heart is in general distinctly marked. The heart-wood alone should be employed in those works in which strength and durability are required. Although the sap-wood is liable to rapid decay when exposed to unfavorable conditions, yet it can be safely used when entirely immersed in water, or when impregnated with certain preserving solutions, or when carefully seasoned and painted.

Timber for building purposes may be divided into two classes: *soft* and *hard*. To the first class belong the pines and firs, to the second the oaks, chestnut, locust, hickory, etc.

PROPERTIES OF TIMBER.—Table 7 shows the weight and strength of timber collected from the experiments of different authorities. It will be seen that the figures vary throughout a very wide range, the difference being caused by the variations in the conditions of the growth of the timber, seasoning and preserveration, and upon the part of the tree from which the specimen was cut, as well as upon the size and form of the piece tested and the method by which the test was applied.

In taking figures from the table the lowest recorded should be taken, applying a large factor of safety to cover defects in the pieces used, which defects may not have existed in the specimens experimented upon.

TABLE 7.

DESCRIPTION AND PROPERTIES OF TIMBER.

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to			Shearing.	
		Tension.	Crushing.	Cross-breaking.	With the Grain	Aross the Grain.
		Pounds per Square Inch.				
ASH (White) ... . Color brown; sap-wood much lighter, often nearly white. Wood heavy, hard, strong, ultimately brittle, coarse-grained, compact. Use: Interior and cabinet work.	40.77	11,000 to 17,000	4000 to 9000	200 to 500	450 to 700	6280
ASH (Red) .... Color rich brown; sap-wood light brown streaked with yellow. Wood heavy, strong, brittle, coarse-grained, compact. Use: As a *substitute* for the more valuable white ash, with which it is often confounded.......	38.96					
ASH (Green)............... Colorbrown; sap-wood lighter. Heavy, hard, strong, brittle, coarse-grained. Use: *Substitute* for white ash...........	44.35					
CEDAR (White)............ Color light brown, turning darker with exposure; the thin sap-wood nearly white. Wood very light, soft, rather coarse-grained. Very durable in contact with the soil. Used for posts, fencing, railway ties, and shingles.	19.72 to 20.70	10,800 to 11,400	5600 to 6000	250 to 380		1300 to 1519
CEDAR (Red).............. Color dull brown tinged with red; the thin sap-wood nearly white. Wood very light, soft, brittle, rather coarse-grained, compact, easily worked. Very durable in contact with the soil. Used for interior finish, fencing, shingles.	23.66		4000 to 7000	200 to 600		

DESCRIPTION AND PROPERTIES OF TIMBER. (*Continued.*)

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to			Shearing.	
		Tension.	Crushing.	Cross-breaking.	With the Grain.	Across the Grain.
		Pounds per Square Inch.				
CEDAR (Central America)..		5000 to 9000		63 to 105		3410
CYPRESS (Yellow)......... .... Color bright, light clear yellow; sap-wood nearly white. Wood light, hard, brittle, close-grained. Durable in contact with the soil. Easily worked. Satiny, polishes well. Has an agreeable resinous odor. Use: Interior finish, cabinet work.	29.80	4000 to 6000	5000 to 7000	380 to 400		
ELM (White).............. Color light clear brown, often tinged with red; sap-wood much lighter. Heavy, hard, strong, tough, very close-grained. Susceptible of polish. Use: Bridge timbers, sills, ties.	45.26	8000 to 13,000	6000 to 10,000	330 to 600		
GUM................. .. ... Color bright brown tinged with red. Heavy, hard, tough, close-grained, compact. Inclined to shrink and warp badly in seasoning. Susceptible of a beautiful polish. Use: Boards and clapboards, and as a *substitute* for black walnut.	36.83	15,000 to 18,000	6240 to 7480	390 to 570		5890
HICKORY .... Color brown; the thin and more valuable sap-wood nearly white. Wood heavy, very hard and strong, tough, close-grained, compact, flexible. Use: Handles for implements, etc.	46.16 to 52.17	12,800 to 18,000	7000 to 10,000	500 to 800		6045 to 7285
HEMLOCK....... .... N. and S. Atlantic....... Pacific.................. Color light brown tinged with red, or often nearly white. Sapwood somewhat darker. Wood light, soft, not strong,	26.42 32.29	8700	4500 to 7420	300 to 580		2750

DESCRIPTION AND PROPERTIES OF TIMBER. (*Continued.*)

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to			Shearing.	
		Tension.	Crushing.	Cross-breaking.	With the Grain.	Across the Grain.
		Pounds per Square Inch.				
brittle, coarse, crooked-grained. Difficult to work. Liable to wind-shake and splinter. Not durable. Use: Rough lumber for construction. Two varieties of the northern are recognized, red and white.						
LOCUST. Color brown, or more rarely light green; sap-wood yellow. Heavy, hard, strong, close-grained, compact. Very durable in contact with the ground. Use: Posts, turning.	45.70	10,500 to 24,800	7000 to 11,700	500 to 850		7176
LIGNUM VITÆ. Color rich yellow brown, varying to almost black; sap-wood light yellow. Heavy, hard, strong, brittle, close-grained, compact. Difficult to work, splits irregularly. Use: Sheaves of blocks.	71.24 to 83.00	10,000 to 12,000	8000 to 9600	450		
MAPLE (Hard). Color light brown tinged with red; sap-wood lighter. Heavy, hard, strong, tough, close-grained, compact. Susceptible of a good polish. Use: Flooring, interior finish.	43.08	8000 to 10,000	7000 to 9940	360 to 800		6355
MAPLE (White). Light, hard, strong, brittle, close-grained, compact. Easily worked. Use: Flooring, furniture.	32.84	8000 to 10,000	6000 to 7500	320 to 530		
MAHOGANY (Cent. America. Color red-brown of various shades and degrees of brightness. Often very much varied and mottled. Inferior qualities contain a large number of gray specks. Wood strong, durable, flexible when green, brittle when dry, is very free	35.00	2300 to 17,900	6000	400		

DESCRIPTION AND PROPERTIES OF TIMBER. (*Continued.*)

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to Tension.	Resistance to Crushing.	Resistance to Cross-breaking.	Shearing With the Grain.	Shearing Across the Grain.
		Pounds per Square Inch.				
from shakes; is seldom attacked by dry rot or worms. Requires care in seasoning; if seasoned too rapidly is liable to split into deep shakes. Use: Interior finish, handrails, patterns, etc.						
OAK (White).............. Color brown; sap-wood light brown. Wood heavy, strong, hard, tough, close-grained. Checks if not carefully seasoned. Use: Interior finish, cabinet-making.	46.85	10,250 to 19,500	4684 to 9500	280 to 730	752 to 966	4425
OAK (Chestnut)........... Color dark brown; sap-wood much lighter. Wood heavy, hard, strong, close-grained. Checks badly in drying. Durable in contact with the soil. Use: Railroad ties.	53.63					
OAK (Live)................. Color light brown or yellow: sap-wood nearly white. Wood very heavy, hard, strong, tough, close-grained, compact. Difficult to work. Polishes.	59.21	10,000 to 16,380	8000 to 10,000	800 to 480		8480
OAK (Red and Black)...... Color light brown or red. Heavy, hard, coarse-grained. Checks in drying. Use: Interior finish and furniture.	40.75	10,000	4000 to 8500	390 to 730		
PALMETTO (Florida)........ Color light brown. Wood light, soft, fibres dark-colored. Hard and difficult to work. Use: Piles. Is impervious to the attacks of the *Teredo*, and very durable under water.	27.44					
PINE (White)............... Color light brown, often slightly tinged with red; sap-wood nearly white. Wood light, soft, very close, straight-grained. Easily worked. Polishes.		3000 to 11,000	3000 to 6650	220 to 460	225 to 423	2480

DESCRIPTION AND PROPERTIES OF TIMBER. (*Continued.*)

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to Tension.	Resistance to Crushing.	Resistance to Cross-breaking.	Shearing. With the Grain.	Shearing. Across the Grain.
		Pounds per Square Inch.				
Use: Interior finish, windows, doors, etc						
Can., N. Atlantic States.	24.02					
N. Pacific coast..........	24.35					
California................	22.00					
Colorado................	27.00					
Arizona..................	30.39					
PINE (Red), *Norway Pine*. Color light red; sap-wood yellow or white Wood light, hard, coarse-grained, compact. Resin-passages few, not conspicuous. Use: All purposes of construction.	30.25	5000 to 13,000	6000 to 7500	280		
PINE (Yellow), *Long-leafed* Color light red or orange: sap-wood nearly white. Wood heavy, hard, strong, tough, coarse-grained; compact. Durable. Cells resinous and dark-colored. Use: All purposes of construction.	43.62	6000 to 31,000	5000 to 9500	370 to 840	286 to 415	4340
PINE (Yellow), *Short-leafed* Color orange; sap-wood white. Wood varying greatly in quality and amount of sap. Heavy, hard, coarse-grained, compact. Cells broad, very resinous; resin-passages numerous, large. Medullary rays numerous. Use: All purposes of construction. Frequently substituted for long-leafed pine, which is superior.	38.40	5000 to 10,000	4000 to 9000	160 to 370		5000
PINE (Oregon) (*Douglas Fir*) Color varying from light red to yellow; sap-wood nearly white. Wood hard, strong, varying greatly with age, conditions of growth, and amount of sap. Difficult to work. Durable. Use: All kinds of construction. Two varieties, red and yellow; red considered less valuable than yellow.	32.14	9000 to 14,000	4880 to 9800	300 to 700		

DESCRIPTION AND PROPERTIES OF TIMBER. (*Continued.*)

Description of Timber.	Weight per Cubic Foot Dry. Lbs.	Resistance to Tension.	Resistance to Crushing.	Resistance to Cross-breaking.	Shearing. With the Grain.	Shearing. Across the Grain.
		Pounds per Square Inch.				
POPLAR (Whitewood)...... Color light yellow or brown; sapwood nearly white. Soft. brittle, very close, straight-grained, compact. Easily worked. Use: interior finish, shingles.	30	7000	4000 to 5700	260 to 470		4418
REDWOOD (Pacific coast)... Color clear, light red; Sap-wood nearly white. Wood light, soft, very brittle, coarse-grained, compact. Easily worked. Polishes. Durable in contact with the soil. Use: Building material and general use	26.23	10,853				
SPRUCE (Black)........... Color light red or often nearly white; sap-wood lighter. Wood light, soft, not strong, close, straight-grained, compact, satiny. Use: Piles, lumber.	28.57	5000 to 10,500	4000 to 7850	360 to 440	253 to 374	3255
SPRUCE (White)........... Color light yellow; sapwood hardly distinguishable. Wood light, soft, not strong, close, straight-grained, compact, satiny. Use: Lumber for construction.	25.25					
WALNUT (White) (*Butter nut*)................... Color light brown, turning dark on exposure. Light, soft, coarse-grained, compact. Easily worked. Satiny. Polishes well. Use: Interior finish.	25.46		5000 to 6800	180 to 470		
WALNUT (Black)........ Color rich dark brown; sap-wood lighter. Heavy, hard, strong, coarse-grained. Checks if not carefully seasoned. Easily worked. Polishes. Use: Interior finish, cabinet-work.	38.11	9000 to 16,000	7500	300 to 650		4728

Seasoning Timber.

The seasoning of timber consists in expelling, as far as possible, the moisture which is contained in its pores. Two methods are practised, natural and artificial.

NATURAL SEASONING is performed simply by exposing the timber freely to the air in a dry place, piled under shelter. The bottom pieces should be placed upon skids (which should be free from decay), raised not less than two feet from the ground. It should be piled in horizontal layers with slats or piling-strips placed between each layer, one near the end of each pile and others at short distances, in order to keep the timber from winding; these strips should not be less than one inch thick. Each pile should contain but one description of timber and the piles should be placed at least 2½ feet apart, so as to allow free circulation of the air.

The timber should be repiled at frequent intervals, and all pieces indicating decay should be removed, to prevent their affecting those which are still sound.

The time required for natural seasoning varies according to the character of the wood and its dimensions.

The following table shows the average time required for the woods named:

White-pine board	1	year
" " plank 2 in. thick	1½	"
" " " 3 " "	2	"
Southern heart-pine 1 in. thick	1	"
Black walnut 1 " "	1½–2	"
" " 4 " "	4	"

Hemlock will dry out sufficiently to be used as joists in from five to seven months; oak and ash approximate walnut in the length of time required.

WATER SEASONING is total immersion of timber in water for the purpose of dissolving the sap, and when thus seasoned it is less liable to warp and crack, but is rendered more brittle, and if kept too long immersed will upon being brought into the air become brashy and useless. Two weeks is about the usual time it is kept under water. After removal from the water it must be thoroughly dried, with free access of air, and turned daily.

ARTIFICIAL SEASONING.—The best method consists in exposing the timber to a current of hot air in a drying-kiln. The best temperature for the hot air varies with the kind and dimensions

of the timber; thus for oak the temperature required is about 105° F. and for pine 180° to 200° F.

The time required for drying varies with the thickness.

Too high temperatures evaporate the moisture too rapidly, and the timber cracks.

Shrinkage and Expansion of Timber.

During the drying or seasoning process timber shrinks considerably; below about 30 per cent of moisture it shrinks nearly as much as it dries; that is to say, when timber dries down from 30 per cent of moisture to 10 per cent moisture it dries out or loses in weight about 20 per cent of its dry weight. It also loses about 20 per cent of its dry volume. A board that is 1 foot wide at 30 per cent moisture is only 11⅝ inches wide at 10 per cent moisture. or a board 4 inches wide at 20 per cent moisture is only about 3⅞ inches wide at 10 per cent moisture. The shrinkage lengthwise is very slight.

On account of the very large radial fibres (medullary rays) in oak wood this kind of timber shrinks mostly in a circumferential direction, and all timber shrinks more circumferentially than radially, since all woods have those medullary rays to a greater or less extent. It is for this reason that "quarter-sawed" (radial-sawed) lumber is more satisfactory than "flat-sawed" for all kinds of furniture and house trimmings. For flooring, quarter-sawed or "rift-sawed" boards, presenting an "edge-grain" surface, is far preferable to "flat-grain," because it wears evenly and does not sliver on the surface.

The shrinkage of different woods is about as follows:

Cedar, Canada	from	14	to	13.25	inches
Elm	"	11	"	10.75	"
Oak	"	12	"	11.625	"
Pine (Northern pitch)	"	10×10	"	9.75×9.75	"
" (Southern pitch)	"	18.375	"	18.25	"
" (white)	"	12	"	11.875	"
" (yellow Northern)	"	18	"	17.875	"
Spruce	"	8.5	"	8.375	"

EXPANSION OF TIMBER DUE TO THE ABSORPTION OF WATER.

	Pine.	Oak.	Chestnut.
Elongation, per cent	0.065	0.085	0.165
Lateral expansion, per cent	2.6	3.5	3.65

Expansion of Timber by Heat.

White pine for 1 degree F. 1 part in 440.530 or for 180 degrees 1 part in 2447, or about one third of the expansion of iron.

Durability and Decay of Timber.

The durability of wood is subject to too great variation to have any limits placed upon it, depending almost entirely upon the conditions to which it is exposed, as to heat and moisture, attacks of insects, etc. Well-seasoned wood in dry situations or in well-ventilated situations with uniform state of moisture or dryness (moisture preferred) should never decay. Timber kept constantly wet may become softened and weakened, but it does not necessarily decay. Various kinds of timber, such as elm, alder, oak, and beech, possess great durability in this condition.

The condition which is least favorable to durability is alternate wetness and dryness, or a slight degree of moisture, especially if accompanied by heat and confined air.

The season and manner of felling and working are important in determining the life. Timber felled in winter is more durable than that felled in summer. Hewed wood is also more durable than sawed from the fact that the pores are closed and the fibre compacted by the blows, while the saw tears the fibre and opens it.

Besides decomposition and decay, timber both in its growing and converted states is subject to the attacks of worms and insects ; these are often selective in their attacks ; the resinous woods, ironwood, and palmetto are not readily attacked. When the insects exist in large numbers they remove so much of the wood as seriously to impair its strength.

Dry Rot is the most formidable kind of decay to which timber is subject. It is caused by a fungus, whose spawn in the sap-wood, on the introduction of moisture, causes fermentation, and the decay of the tissues follows, and in a short time the wood will crumble beneath the touch.

Dry rot occurs most frequently in ill-ventilated places. The ends of timbers built into walls, woodwork fixed to walls before they are dry, are quickly affected. Painting and tarring the surface of unseasoned timber has the same effect. An excess of moisture prevents the growth of the fungus, but a moderate warmth, combined with damp and want of air, accelerates it.

The season of felling influences the resistance to dry rot, timber felled in winter being less liable to attack, but the germs of

decay may remain inert in the wood for a long time, and finally become evident and active if the conditions be favorable. Once established in the wood it is very difficult to eradicate, the only remedy being to remove all trace of the fungus and disinfect.

Healthy wood is liable to receive germs from the air and water, and these sources are of more danger than the germs contained in the wood itself.

The colors of the fungus are various: sometimes white, grayish white with violet, often of yellowish brown or a deep shade of fine rich brown.

The softer and more porous woods are the more liable to decay by dry rot.

Detection of Dry Rot.—In the first stages of rottenness the timber swells and changes color, and is often covered with fungus or mouldiness, and emits a musty odor.

In the absence of any outward fungus or other visible sign a hole may be bored into the wood: the appearance of the dust extracted and especially the odor will indicate the presence of dry rot.

Sometimes the rot only appears in the form of reddish or yellow spots, which upon being scratched show that the fibres have been reduced to powder.

Wet Rot is caused by the presence of moisture, which decomposes the tissues of the wood, particularly those of the sap-wood. Wood felled between April and October is especially liable to wet rot.

Common Rot is caused by the wood being piled to season in badly ventilated sheds. Outward indications are yellow spots upon the ends of the pieces, and a yellowish dust in the checks and cracks, particularly where the pieces rest upon the piling-strips.

Worms.—Of worms the two most active are the *Teredo navalis* and the *Limnoria terebrans*. The *Teredo* is most active in salt water. It is found in both warm and cold climates. It avoids fresh water and prefers clear water to that which is muddy.

The *Teredo* is first deposited upon the timber in the shape of an egg, from which in time it emerges a small worm; this worm soon becomes larger and commences its depredations.

Furnished with a shelly substance in its head, shaped like an auger, it bores into the wood, in an upward course parallel to the grain; at the same time it lines the hole it makes with a thin coating of carbonate of lime, and closes the opening with two small lids; hence it prefers a calcareous seashore.

As the work of the *Teredo* advances its size increases. Worms two feet long and three fourths inch in diameter have been found.

The *Limnoria terebrans* resembles in appearance a very small wood-louse and is most active in brackish water and prefers a silicious shore, formed by the decomposition of silicious rocks. As many as twenty thousand will appear on a surface only twelve inches square. The *Limnoria* prefers soft woods and avoids knots; it does not bore, but destroys the wood by eating the surface at the rate of from one to three inches per annum.

Both the *Teredo* and *Limnoria* confine their work to a space between high- and low-water marks, showing that they require both air and water.

The *Lycoris fucata* is the enemy of the *Teredo;* it is a little worm with legs, something like a centipede; it lives in the mud, crawls up the pile inhabited by the *Teredo,* enters the tunnel in which it is ensconced, eats the *Teredo,* enlarges the entrance to the tunnel, and then lives in it.

Many processes have been tried to protect timber from the ravages of those worms; the most successful appears to be impegnation with creosote.

Processes for Preserving Timber.

From the earliest times attempts have been made to preserve wood, and a vast number of processes and materials have been experimented with. A few of the successful methods are as follows:

BURNETT'S PROCESS, OR BURNETTIZING.—Impregnation with chloride of zinc. The operation is performed in large metal cylinders called retorts, and is conducted about as follows: The load of timber, called a "charge," is placed in the retort and the heads or doors closed and bolted. A vacuum is then produced in the retort. When this has reached about twenty inches live steam at about 20 pounds' pressure is let in and continued for about four or five hours. It is then blown off and the retorts drained. A second vacuum is produced of from twenty-two to twenty-six inches. The zinc chloride solution is introduced under pressure; this pressure is raised to about 120 to 150 pounds per square inch and maintained until the required quantity of solution is injected into the timber; when this has been accomplished the surplus fluid is drawn off, the doors opened, and the charge pulled out.

The solution of zinc chloride, called the "stock solution," con-

sists of about 43 per cent pure zinc chlorine, 2 per cent of impurities (iron, aluminum, lead, etc.), and 55 per cent of water. The standard solution when ready for use should register $2\frac{1}{8}$° Baumé at 60° F. The solution is heated by steam passed through coils to about 150° F. before being pumped into the charge.

To provide means for watching the effect of the various steps in the process the retorts are provided with thermometers and vacuum-gauges, the steam-pipes with pyrometers, the tanks with gauges, the condenser with a measuring-well, and the solution is taken from a gauged measuring-tank.

The quantity of zinc injected per cubic foot of timber is about $\frac{24}{100}$ of a pound. The time required for treatment ranges from 8 to 12 hours, depending upon the condition of the timber; the greener the wood the more easily it is impregnated.

Burnettizing has not been so successful in the United States as in Europe.

WELLSHOUSE'S PROCESS is a modification of Burnett's. The timber is steamed in a cylinder one to three hours (according to size); zinc chloride and glue solution is then forced in, after which tannin is injected, the purpose of the glue being to combine with the tannic acid in the wood, precipitating the glue as an insoluble compound and retaining the zinc. The tannic acid is added to precipitate the excess of glue.

THILMANY'S PROCESS.—Impregnation with zinc or copper sulphate. For this process green wood is preferred, the dry requiring to be longer steamed. The timber is run on flat cars into a cylinder, steam is applied to drive out the sap, and an air-pump is connected to draw air and condensed moisture and form a vacuum. The cylinder is then filled with a $1\frac{1}{2}$ per cent solution of zinc or copper sulphate and a pressure of 80 to 100 pounds applied until charged. The sulphate solution is then drawn off and a 1 per cent solution of barium chloride similarly charged. The strength of the solution is varied according to the class of timber to be impregnated.

KYAN'S PROCESS.—Saturating with corrosive sublimate.

BURCHERI'S PROCESS.—Impregnation with sulphate of copper under a pressure of about 15 lbs. per sq. in.

CREOSOTING (BETHELL'S PROCESS).—Impregnating with dead oil of coal-tar or distillates from wood-tars.

The timber is placed in cylinders, steam turned on and continued until the mass is thoroughly heated and the sap vaporized. The steam and sap are drawn off by a pump, a partial vacuum formed, and the cylinder filled with the oil, which is usually heated to a

temperature of about 160°. A pressure varying from 150 to 200 lbs. is applied and continued until the gauge stands constant, showing that no more oil is being absorbed. The oil is then drawn off and the charge removed.

The details of the operation vary in different establishments. The time required for steaming varies from 30 minutes to several hours according to the variety of wood under treatment, green and hard timber requiring more than seasoned or soft timber. The amount of oil absorbed by the timber also varies according to its variety; from 12 to 18 pounds per cubic foot appears to be the usual amount. The treatment of a charge requires on an average 24 hours.

PAYNE'S PROCESS.—Impregnating the wood while in a vacuum with sulphate of iron, followed by a solution of sulphate of lime or soda. This process is also said to render the wood incombustible.

SEELEY'S PROCESS is a modification of Bethell's. The timber is immersed in creosote at a temperature of 212° to 300° F. for a time sufficient to expel the moisture, the hot oil is drawn off and replaced by cold oil. About 4 lbs. per cubic foot is said to be absorbed by this process.

VULCANIZING is the process of rendering the sap insoluble and undecomposable within the cells by means of heat. To do this the wood is subjected to such pressure of air, in a closed vessel, that the sap will not vaporize on the application of heat. Heat is then applied gradually, the pressure being maintained or increased as the temperature rises. About 400° F. is generally sufficient to vulcanize ordinary woods. The time required is about 8 hours for soft and from 10 to 20 hours for hard woods.

Inspection of Treated Timber.

Inspect for penetration by boring two ½-inch holes at a distance of from 3 to 15 feet from each end, according to the length of the stick ; the two holes near each end to be diametrically opposite, and the pair on one end to be at right angles to that on the other. In special cases other holes may be bored. Care must be taken not to bore into a check. After inspection the holes are to be plugged with preserved plugs turned to a driving fit.

TESTING TIMBER TREATED WITH ZINC CHLORIDE.—At intervals during the progress of the impregnation and whenever any charge shows some change in the treatment as to vacuum, time or amount of pressure, and after each change in kind, quality, or dryness of timber four samples are taken from a charge consisting of pieces of average grain—one heaviest, one lightest, and two average weight. Each piece is bored in the middle of its width and length with a one-inch auger. The first half inch of the borings is thrown away, after which each inch of borings is preserved separately and designated as 1-inch, 2-inch, 3-inch, etc., specimens. Each specimen is burned to an ash, over a gasoline jet, in a porcelain roasting-dish, in contact with the air. The ashes are carefully collected in a platinum cup, distilled water added, with a slight excess of hydrochloric acid, converting the zinc oxide into zinc chloride. It is then filtered into a test-tube and the zinc hydrate thrown down with sodium carbonate, making a white flocculent precipitate. The liquid is then made up with distilled water to three drachms. The resulting milky liquid is compared with standard liquids in tubes of the same size as the test-tubes, each tube containing three drachms. The standard liquids are graded to represent 6, 9, 12, 15, 18, 21, and 24 one-hundredths of a pound of zinc chloride per cubic foot of timber. The maximum of zinc chloride per cubic foot of timber is 24 one-hundredths of a pound.

Form of Report.

WOOD-PRESERVING.

Report of........... ....*Creosoted at*............
................*189*....

Retort No.....

Kind of timber......................................
Charge number....
Date going in................
Date coming out................
Time: Load in at.......................
Pressure began at................
Pressure left off at................
Load out at.......................
Total time................
Temperature: When filled................
At end of pressure when oil is let out of steam................
Pressure: At beginning........
At end........
Condensation: Quantity of oil pumped.................
Number of pieces in charge........
Number of cubic feet in charge........
Length, breadth, and thickness of pieces......
Maximum penetration: Ends....Centre....
Minimum penetration: Ends.....Centre....
Amount of creosote per cubic foot............

Form of Report.

WOOD-PRESERVING.

Report of.......................*Burnettized at*............
................*189*....

Retort No.....

Charge number....
Date going in................
Date going out................
Number of pieces in charge....
Length, breadth, thickness................
Number of cubic feet in charge........

TIME: Charge in at............
Vacuum begun at............
Inches of vacuum....
Steam turned in at............
Steam-pressure........
Vacuum begun at................
Injection begun at..... ......
Pressure begun at............
Pressure left off at............
Charge out at ....
Total time........

TEMPERATURE: At end of live steam....
When injection began....
At end of pressure....
When solution is let off....

PRESSURE: At beginning................
At end................

Quantity of solution pumped in................
Quantity drawn off................

REPORT OF TESTS.

PILES: Number of specimens tested....
Length of piles....................
Diameter of piles........
Maximum penetration: Butt........Tip........
Minimum penetration: Butt........Tip........

TIMBER: Number of pieces tested....
Length........
Breadth........
Thickness........
Weight........
Solution, and penetration per cubic foot...........

REMARKS: Penetration uniform or irregular..................
Depth of penetration............
Effect on timber—splitting, checking, or cracking...
....

TABLE 7A.

BOARD MEASURE.

Width in in.																			
0																			
1	.0833	.1250	.1667	.2083	.2500	.2917	.3333	.3750	.4167	.4583	.5000	.5833	.6667	.7500	.8333	.9167	1 000	1 167	1 333
1½	.1250	.1875	.2500	.3125	.3750	.4375	.5000	.5625	.6250	.6875	.7500	.8750	1 000	1 125	1 250	1 375	1 500	1 750	2 000
2	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	1 000	1 167	1 333	1 500	1 667	1 833	2 000	2 333	2 667
2½	.2083	.3125	.4167	.5208	.6250	.7292	.8333	.9375	1 042	1 146	1 250	1 458	1 667	1 875	2 083	2 292	2 500	2 917	3 333
3	.2500	.3750	.5000	.6250	.7500	.8750	1 000	1 125	1 250	1 375	1 500	1 750	2 000	2 250	2 500	2 750	3 000	3 500	4 000
3½	.2917	.4375	.5833	.7292	.8750	1 021	1 167	1 313	1 458	1 604	1 750	2 042	2 333	2 625	2 917	3 208	3 500	4 083	4 667
4	.3333	.5000	.6667	.8333	1 000	1 167	1 333	1 500	1 667	1 833	2 000	2 333	2 667	3 000	3 333	3 667	4 000	4 667	5 333
4½	.3750	.5625	.7500	.9375	1 125	1 313	1 500	1 688	1 875	2 063	2 250	2 625	3 000	3 375	3 750	4 125	4 500	5 250	6 000
5	.4167	.6250	.8333	1 042	1 250	1 457	1 666	1 875	2 083	2 292	2 500	2 917	3 333	3 750	4 167	4 583	5 000	5 833	6 667
5½	.4583	.6875	.9167	1 146	1 375	1 604	1 833	2 063	2 292	2 521	2 750	3 208	3 667	4 125	4 583	5 042	5 500	6 417	7 333
6	.5000	.7500	1 000	1 250	1 500	1 750	2 000	2 250	2 500	2 750	3 000	3 500	4 000	4 500	5 000	5 500	6 000	7 000	8 000
7	.5833	.8750	1.167	1 458	1 750	2 042	2 333	2 625	2 917	3 208	3 500	4 083	4 667	5 250	5 833	6 417	7 000	8 167	9 333
8	.6667	1 000	1 333	1 667	2 000	2 333	2 667	3 000	3 333	3 667	4 000	4 667	5 333	6 000	6 667	7 333	8 000	9 333	10 67
9	.7500	1.125	1.500	1 875	2 250	2 625	3 000	3 375	3 750	4 125	4 500	5 250	6 000	6 750	7 500	8 250	9 000	10 50	12 00
10	.8333	1 250	1 667	2 083	2 500	2 917	3 333	3 750	4 167	4 583	5 000	5 833	6 667	7 500	8 333	9 167	10 000	11 67	13 33
11	.9167	1 375	1 833	2 292	2 750	3 208	3 666	4 125	4 583	5 042	5 500	6 417	7 333	8 250	9 167	10 08	11 000	12 83	14 67
12	1 000	1 500	2 000	2 500	3 000	3 500	4 000	4 500	5 000	5 500	6 000	7 000	8 000	9 000	10 00	11 00	12 00	14 00	16 00
13	1 083	1 625	2 167	2 708	3 250	3 792	4 333	4 875	5 417	5 958	6 500	7 583	8 666	9 750	10 83	11 92	13 00	15 17	17 33
14	1 167	1 750	2 333	2 917	3 500	4 083	4 667	5 250	5 833	6 417	7 000	8 167	9 333	10 50	11 67	12 83	14 00	16 33	18 67
15	1 250	1 875	2 500	3 125	3 750	4 375	5 000	5 625	6 250	6 875	7 500	8 750	10 00	11 25	12 50	13 75	15 00	17 50	20.00
16	1 333	2 000	2 667	3 333	4 000	4 667	5 333	6 000	6 667	7 333	8 000	9 333	10 67	12 00	13 33	14 67	16 00	18 67	21 33
18	1 500	2 250	3 000	3 750	4 500	5.250	6 000	6 750	7 500	8 250	9 000	10 50	12 00	13.50	15 00	16 50	18 00	21 00	24.00
20	1.667	2 500	3 333	4 167	5.000	5.833	6.667	7.500	8.333	9 167	10.000	11.67	13 33	15.00	16.67	18.33	20.00	23 33	26.67

Measurement of Timber.

Timber is measured when bought in the market either by the cubic foot or by *board measure*. The unit of the latter is a square foot of surface by one inch in thickness, and is denoted by the abbreviation B. M.

Rule.—Multiply together the three dimensions, width and thickness in inches and the length in feet, divide the product by 12, and the quotient will be the board measure.

Sawn or hewn timber is often measured by the cubic foot.

Round timber is measured by multiplying the length by the square of one-fourth its mean girth to obtain the cubic contents. If L = length in feet and C the mean circumference of the log, i.e., the half sum of the girth at the ends, also measured in feet, the volume in cubic feet is given by the formula

$$\text{Volume} = L\,\frac{C^2}{4} = \frac{LC^2}{13}.$$

When the length is in feet and the girth in inches, divide the result obtained by 144 to obtain cubic feet.

Inspection of Timber.

In examining timber the points to be observed are quality and dimensions. All condemned pieces should be marked with paint or a branding-iron.

Appearance of Good Timber.—There are certain appearances which are characteristic of strong and durable timber, to what class soever it belongs.

In the same species of timber that specimen will in general be the strongest and the most durable which has grown the slowest, as shown by the narrowness of the annual rings.

Good timber should be from the heart of a sound tree, the sap being entirely removed, the wood uniform in substance, straight in fibre, free from large or dead knots, flaws, shakes, or blemishes of any kind.

If freshly cut it should smell sweet. The surface should not be woolly, or clog the teeth of the saw, but should be firm and bright, with a silky lustre when planed. A disagreeable odor indicates decay, and a dull, chalky appearance is a sign of bad timber

Good timber is sonorous when struck. A dull, heavy sound indicates decay.

Amongst resinous woods those which have least resin in their pores, and amongst non-resinous woods those which have least sap or gum in them, are in general the strongest and most lasting.

Among colored woods, darkness of color is in general a sign of strength and durability.

If a piece of sound timber be struck lightly with a small hammer or scratched at one end, the sound can be distinctly heard by a person placing his ear against the other end, even if the stick be 50 ft. long; but if the timber be decayed, the sound will be very faint.

Defects of Timber.

Wind shakes. — Circular cracks separating the concentric layers of wood from each other. They are serious defects.

Splits, Checks, and Cracks, extending toward the centre, if deep and strongly marked, render timber unfit for use, unless the purpose for which it is intended will admit of its being split through them.

Brashy Timber.—Timber from trees which have commenced to decay from old age ; indicated by a reddish color, breaking of the wood without splinters, and porosity.

Belted is the term applied to timber which has been killed before being felled. Such timber is objectionable.

Knotty is the term applied to timber containing many knots. The knots, though sound are objectionable when they extend far inwards.

Twisted is the term applied to timber in which the grain winds spirally; such timber is unfit for long pieces.

Heart-shake.—Splits or clefts in the centre of the tree.

Star-shakes.—Several splits radiating from the centre.

Cup-shakes.—Curved splits separating the rings wholly or in part.

Rind-gall.—Curved swelling, usually caused by growth of layers over a spot where a branch has been removed.

Upset.—Fibres injured by crushing.

Foxiness.—Yellow or red tinge, indicating incipient decay.

Dote—Doatiness.—A disease indicated by speckled stains and dulness of sound when struck a quick blow.

To Determine Amount of Moisture in Lumber.

To determine the amount of moisture in lumber, cut a section from a board or stick and weigh it; then dry it in an ordinary stove-oven with a slow fire for an hour or two; then weigh again. The difference in weight divided by the dry weight is the percentage of moisture.

"Thoroughly dry lumber" should not contain more than 10 or 12 per cent of water, and the interior should be as dry as the exterior.

The amount of water contained in wood varies within very wide limits.

Willow........	26.0 per cent	Sycamore.......	27.0 per cent
Mountain ash..	28.3 " "	Beech..........	30.8 " "
Oak..........	34.7 " "	Fir (white).....	37.1 " "
Horse-chestnut	38.7 " "	Alder..........	41.6 " "
Elm...........	44.5 " "	Fir (red)........	45.2 " "
Poplar (white).	50.2 " "	Poplar (black)..	51.8 " "

By "air-drying" the water is not entirely removed; the evaporation continues until an equilibrium is established between the humidity of the air and the hygroscopic power of the wood. By heat, however, 16 to 20 per cent more can be expelled, but at such temperatures that the wood is liable to become brown and decompose. By air-drying 20 to 25 per cent of water can be expelled by from 10 to 12 months' exposure.

ABSORPTIVE POWER OF WOOD.

Kind of Wood.	Percentage of Water Absorbed.	
	Dry Wood.	Creosoted.
Black gum..........................	1.0000	.1250
Cottonwood.........................	.7140	.3470
Oak..................................	.2000	.0625
Spruce..............................	.1754 to .3833	.0236 to .0306
" (burnettized, .2500)..........		
Hard pine...........................	.1600	.0000
White birch.........................	.4300	.1240
Sesquoia gigantea of California.....	.4722	.0000

General Rules for Classifying Lumber.*

The following general rules are intended to serve as a guide in classifying lumber in accordance with the grades named below. While they are intended to apply only to Southern yellow pine, they can be understood to apply in a general way to all merchantable lumber.

YELLOW-PINE LUMBER shall be graded and classified according to the following rules and specifications as to quality; and dressed stock shall conform to the subjoined table of standard sizes, except where otherwise expressly stipulated between buyer and seller.

Recognized Defects in Yellow Pine are *knots* (pin, round, spike, black, encased, loose, or rotten), *knot-holes*, *splits* (either from seasoning, ring-heart, or rough handling), *rotten streaks*, *dote*, *rot*, *worm-holes*, and *pitch-pockets*.

SHAKE.—"Ring-heart" is a shake or cleavage along the plane of an annual ring, usually about half-way between the pith and the circumference. "Shake," or "wind-shake," is a cleavage of the trunk of a tree, while yet standing, due to the action of the wind in bending the trunk. It is usually along the plane of an annual ring, that is to say, concentric with the centre or pith of the tree. "Heart-shake" is a diametrical or radial cleavage through the tree or log. If it occurs after the logs are cut, or in large timbers after they are sawed, it is due to shrinkage in drying. This is a common defect of all oak logs or large timbers.

WANE is a deficiency in width, either over the entire edge or on one corner, caused by a crook in the log.

CROOKS are permanent distortions of the board, due to defective piling or from other causes.

WARP is a twisting of the board into a warped surface.

SEASONING- OR KILN-CHECKS are either very small or large cracks caused by drying the surface of the board, with its accompanying shrinkage, while the interior is still wet.

BLUE SAP, a discoloration which green yellow pine is subject to, especially the sap portion, if not at once piled for drying or placed in a dry kiln.

PITCH-STREAKS are longitudinal openings, sometimes of considerable size, as $\frac{1}{8}$ to $\frac{1}{4}$ inch wide and several inches, or even feet, long, filled with resin.

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* Adopted by the Southern Lumber Manufacturers' Association, 1895.

Bright Sap shall not be considered a defect in any of the grades provided for and described in these rules. The restriction or exclusion of bright sap constitutes a special class of material, which can be secured only by special contract.

Firm Redheart shall not be considered a defect in common grades.

Defects in Rough Stock, caused by improper manufacture or drying, will reduce grade, unless they can be removed in working such stock to standard sizes.

Imperfect Manufacture in dressed stock, such as *chipped*, *grain-splintered* or *torn places*, *broken knots* on edge of ship-lap, insufficient tongue on flooring, etc., shall be considered defects, and reduce grade accordingly.

A **Standard Knot** is sound, and not over 1¼ inches in diameter.

A **Pin-knot** is sound, and not over 1⅛ inches in diameter.

Any piece that will not work one half its size shall be classed as a dead cull.

The **Grade** of all regular stock shall be determined by the number and position of the defects visible in any piece. The enumerated defects admissible in any given grade are intended to be descriptive of the coarsest pieces such grade may contain. The average quality of the grade should be midway between such pieces and the defects allowed in the next higher grade.

Lumber or timber sawed for specific purposes, as bridge timbers, etc., must be inspected with a view to the adaptability of the piece for the use intended.

In finishing, flooring, etc., the enumerated defects admissible in a given grade apply only to the face side of the piece, but the reverse face should not admit defects that would render the piece unsuitable for the purpose intended.

Standard Lengths are multiples of 2 feet from 10 to 20 feet, inclusive, for boards and strips, and from 10 to 24 feet, inclusive, for dimension joists and timbers. Longer or shorter lengths than those herein specified are special. Odd lengths, if below 24 feet, shall be counted as of the next higher even length.

On stock shipments of 8-inch and under no board shall be admissible that is more than ¼ inch scant; on 10-inch not more than ⅜ inch, and on 12-inch not more than ½ inch scant of specified width.

Yellow pine of better grade than No. 1 common up to 4 inches in width is classified according to grain, as *edge-grain* and *flat-grain*. Edge-grain yellow pine has been variously designated as

"rift-sawn," "straight-grain," "vertical-grain," and "quarter-sawed," all being commercially synonymous terms. Edge-grain stock is specially desirable for flooring, and admits no piece in which the angle of the grain exceeds 45 degrees from the vertical, thus excluding all pieces that will sliver or shell from wear. Such stock as will not meet these requirements is known as flat-grain.

All dressed and matched stock shall be measured and sold "strip count," i. e., full size of rough strip from which such stock is made—3, 4, 5, and 6 inches.

The foregoing general observations shall apply to and govern the following detailed descriptive enumeration of recognized grades.

Rules for Grading Finished Lumber.

The following rules for grading apply to all kinds of finishing stock, whether for interior or outdoor work. In these rules the expressions "S. 1S." or "S. 2S." mean "surfaced one side" or "surfaced two sides," respectively Also "S. 1S. 1E." mean "surfaced one side and one edge." By surfacing is meant planing or running it through a planing-machine. It may still require hand-dressing for the best work. Nearly all sawmills now dry their lumber and run it through the planer in order to save the extra freight on the rough and green lumber.

Grades.—First and second clear; third clear, barn and roofing stocks.

First and Second Clear Finish.—1 inch, 1S. or 2S., up to and including 10 inches wide, must show one face clear from all defects; 33⅓ per cent of any shipment of boards 12 or 14 inches wide will admit two pin-knots or one standard knot, slight pitch-streak, or small pitch-pocket, or sap-stain not over 1½ inches wide running across the face, or small kiln- or seasoning-checks, but no two of these defects shall appear in a single piece; 16-inch wide will admit of two defects allowed in 12-inch or their equivalent; wider than 16-inch will admit proportionately more defects. Pieces otherwise admissible in which the point of the grain has been loosened or slivered in dressing one face side should be put in lower grade. Defective dressing on reverse face of finishing is admissible. In case both faces are desired clear special contract must be made.

Third Clear Finish.—1 inch, S. 1S. or 2S., up to and including 10 inches wide, may have not more than two of the

following defects on best or face side: three pin-knots, one standard knot, three sap-stains 2 inches wide running across the face or their equivalent, two pitch-pockets, slight pitch-streaks kiln or seasoning checks, torn places, and wane which does not enter more than 1 inch, nor extend more than 2 feet; 12-inch will admit three of the above defects or their equivalent. This grade is suitable for paint finish.

1¼, 1½, and 2 inch, S. 1 or 2 S., shall take 1-inch inspection, and unless otherwise agreed between buyer and seller, shall be subject to inspection on face or best side only.

BARN and NOVELTY-SIDING, SHIP-LAP and GROOVED ROOFING shall be 8, 10, and 12 inches wide, and consist of boards below third clear which are sound and water-tight, free from coarse knots, and wane over 1 inch wide and extending more than 3 feet in any piece. Pitch, except in narrow streaks, should be excluded.

EDGE-GRAIN FLOORING. (Grades: First Clear, Second Clear). —First clear edge-grain flooring must be well manufactured, and free from all defects on face side of strip.

Second clear edge-grain flooring will admit of three pin-knots, or one standard knot, or small pitch-pocket, or blue-sap stain not to exceed 10 per cent of the face.

FLAT-GRAIN FLOORING. (Grades: A flat, B flat.)—*A-flat* flooring may contain two pin-knots or one small pitch-pocket, but shall be free from other defects, and must be well manufactured. Pieces in which the point of the grain has been loosened in dressing should be put in lower grade.

B-flat flooring may have any two of the following defects: Three pin-knots or one standard knot; slight sap-stains, slight torn places and defects in manufacture, narrow pitch-streaks, and seasoning-checks. When all other defects are absent, blue-sap stain in any quantity shall be admitted.

COMMON FLOORING. (Grades: No. 1 Common, No. 2 Common.) —*No.* 1 *Common* must be manufactured from sound stock. In addition to the defects described in B flat, also admits of sound knots, blue sap and firm redheart in any quantity, pitch, and slight shake, but must "lay" without waste. No division as to grain is made in this grade.

NO. 2 COMMON FLOORING includes all pieces that will not grade No. 1 common, which can be laid without wasting more than one-fourth the length of any piece. This grade will admit imperfections which do not render the piece unfit for use in cheap floors and roof-sheathing.

CENTRE-MATCHED FLOORING shall be required to come up to grade on one face only.

CEILING. (Grades: A, B, C.)—*A ceiling* shall be free from all defects on face, and well manufactured.

B Ceiling will admit slight imperfections in dressing. Three pin-knots, or one standard knot, pitch-streaks or small pitch-pockets, or blue sap-stain not to exceed 10 per cent of the face; but not more than two of these defects to be admitted in any piece.

C Ceiling conforms to grade No. 1 common flooring, and is suitable for paint finish. Will admit imperfections that do not prevent its use without waste.

WAGON BOTTOMS. (Grades: A, B.)—Wagon bottoms shall be graded the same as flat-grain flooring.

BEVEL AND DROP SIDING. (Grades: A, B, C.)—Shall be graded according to ceiling rules, but will admit more blue stain, and, except in grade C, should exclude pitch. Slight additional imperfections on the thin edge of bevel-siding which will be covered by the lap are admissible.

PARTITION. (Grades: A, B, C.)—Partition shall conform to ceiling grades, but must meet the requirements of the specified grade only on one face. The reverse face shall not be more than one grade lower.

MOULDED CASINGS AND BASE. (Grades: First Clear, Second Clear.)—*First clear* shall be free from all defects on face and perfect in manufacture.

Second clear is suitable for work that is to receive a paint finish, and usually consists of rejections, made after dressing, from stock inspected in the rough as first clear. The defects admitted in B ceiling would be allowed.

Rules for Grading Common Boards and Rough Lumber.

COMMON BOARDS AND SHIPLAP.—No. 1 common boards, S. 1S., and No. 1 common shiplap shall be manufactured from sound stock, of even thickness the entire length. Will admit of any two of the following defects: Wane one-half inch deep on edge and one sixth the length of the piece; tight sound knots, none of which shall be larger than three inches in diameter, or equivalent spike-knots; one split not more than 18 inches long, and blue sap. These boards shall be firm and strong, suitable for use in all ordinary construction, and serviceable without waste.

No. 2 Common Boards and *No. 2 Common Shiplap* admit pieces that fall below No. 1, which are free from the following defects: Rotten streaks that go through the piece, through heart-shakes which extend more than half the length of the piece, and wane over 2 inches wide, exceeding one third the length of the piece. A knot-hole 1½ inches in diameter or its equivalent will be allowed, provided the piece would otherwise grade No. 1 common. Worm-holes and straight splits one fourth of the length of the piece are admissible.

FENCING, S. 1S.—*No. 1 Common Fencing* must be manufactured from sound stock. May contain sound knots equal in diameter to not over one third the width of the piece at any given point throughout its length, but must be free from spike-knots the length of which is over half the width of the piece. Also, free from wane over ½ inch deep on edge and one half the length of any piece measured on one side. This grade must work its full length without waste.

NO. 2 COMMON FENCING shall admit of pieces that fall below No. 1 common which are free from through rotten streaks.

Miscut 1-inch stock in boards and fencing which does not fall below ⅞ inch thick shall be admitted in No. 2 common provided that the grade of such thin stock is in all other respects as good as No. 1 common.

DIMENSION S. 1S. 1E.—*No. 1 Common Dimension* shall be manufactured from sound stock, and be free from loose and unsound knots, and large knots so located as to materially impair the strength of the piece; will admit of seasoning-checks and heart-shakes that do not go through, of slight wane and such other defects as do not prevent its use as substantial structural material.

No. 2 Common Dimension admits all pieces falling below No. 1 common which are free from through rotten streaks and sound enough to be used without waste.

Miscut 2-inch stock which does not fall below $1\frac{1}{2}$ inches shall be admitted in No. 2 common provided that the grade of such thin stock is in all other respects as good as No. 1 common.

In boards, fencing and dimension stock falling below No. 2 grade and excluding dead culls shall be classed as No. 3.

Dressed Timbers shall conform in grade to the specifications applying to rough timbers of similar size.

Rough Yellow Pine. Flooring-strips and Finishing.—Flooring-strips are 3, 4, 5, and 6 inches wide when green; square-edged and evenly manufactured.

Finish must be evenly manufactured, and shall embrace all sizes from 1 inch to 2 inches thick by 6 inches and over in width.

No finishing-lumber, unless otherwise ordered, should measure when dry and rough less than $\frac{1}{16}$ inch scant in thickness. No piece in any shipment of boards and strips shall be more than $\frac{1}{4}$ inch scant on 6- and 8-inch stock, $\frac{3}{8}$ inch scant on 10- and $\frac{1}{8}$ inch scant on 12-inch and wider stock.

Wane and seasoning checks that will dress out in working to standard thicknesses and widths are admissible.

Subject to the foregoing provisions rough finishing shall be graded according to the specifications applying to dress finishing. When like grade of both faces is required special contract should be made.

Common Boards. Fencing and Dimension.—Rough common boards and fencing must be evenly manufactured, and should not be less than $\frac{7}{8}$ inch thick when dry, nor more than $\frac{1}{2}$ inch scant of specified width.

Rough 2-inch Common shall be evenly manufactured and not less than $1\frac{7}{8}$ inches thick when green, or $1\frac{3}{4}$ inches thick when dry. The several widths must not be less than $\frac{1}{8}$ inch over the standard dressing width for such stock. The defects admissible in rough stock shall be the same as those applying to dressed stock of like kind and grade, but such further defects as would disappear in dressing to standard size of such material shall be allowed.

Rough Timbers 6 × 6 inches and larger shall not be more than $\frac{1}{4}$ inch scant when green, and be evenly manufactured from sound stock with not less than three square edges, and must be free from knots that will materially weaken the piece.

Timbers 10 × 10 inches may have a 2-inch wane on one corner, or its equivalent on two or more corners, one fourth the length of the piece. Other sizes may have proportionate defects.

Seasoning-checks and shakes extending not over one eighth the length of the piece are admissible.

Standard Dimensions of the Southern Lumber Manufacturers' Association.*

FLOORING.—The standard of 1″ × 4″ and 6″ shall be $\frac{27}{32}$″ × $3\frac{1}{4}$″ and $5\frac{1}{4}$″; $1\frac{1}{4}$-inch flooring $1\frac{3}{32}$″.

CEILING.—$\frac{3}{8}$-inch ceiling $\frac{5}{16}$-inch; $\frac{1}{2}$-inch $\frac{7}{16}$-inch; $\frac{5}{8}$-inch $\frac{9}{16}$-inch; $\frac{3}{4}$-inch $\frac{11}{16}$-inch. Same width as flooring.

FINISHING.—1-inch S. 1S. or S. 2S. to $\frac{27}{32}$-inch; $1\frac{1}{4}$-inch S. 1S. or S. 2S. to $1\frac{3}{32}$-inch; $1\frac{1}{2}$-inch S. 1S. or S. 2S. to $1\frac{11}{32}$-inch; 2-inch S. 1S. or S. 2S. to $1\frac{3}{4}$-inch.

BOARDS AND FENCING.—1-inch S. 1S. or S. 2S. to $\frac{13}{16}$-inch.

DIMENSION.—	2 × 4	inch	S. 1S. 1E.	to	$1\frac{5}{8} \times 3\frac{5}{8}$	inches.
	2 × 6	"	"	" "	$1\frac{5}{8} \times 5\frac{5}{8}$	"
	2 × 8	"	"	" "	$1\frac{5}{8} \times 7\frac{1}{2}$	"
	2 × 10	"	"	" "	$1\frac{5}{8} \times 9\frac{1}{2}$	"
	2 × 12	"	"	" "	$1\frac{5}{8} \times 11\frac{1}{2}$	"
	4 × 4	"	$\frac{3}{8}$ inch off side and edge.			
	4 × 4	"	S. 4S. $\frac{1}{4}$ inch off each side.			

Inspection of Yellow-pine Lumber.

(Rules adopted by the New York Lumber-Trade Association.)

SCANTLING shall embrace all sizes from two to five inches in thickness and two to six inches in width. For example: 2 × 2, 2 × 3, 2 × 4, 2 × 5, 2 × 6, 3 × 3, 3 × 4, 3 × 5, 3 × 6, 4 × 4, 4 × 5, 4 × 6, 5 × 5, and 5 × 6.

PLANK shall embrace all sizes from one and one-half to five inches in thickness by seven inches and up in width ($1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5 × 7 and up wide).

DIMENSION SIZES shall embrace all sizes six inches and up in thickness by seven inches and up in width, including six by six. For example: 6 × 6, 6 × 7, 7 × 7, 7 × 8, 8 × 8, 8 × 9, and up.

STEPPING shall embrace one to two and one-half inches in thickness by seven inches and up in width. For example: 1, $1\frac{1}{4}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ × 7 and up wide.

* These particular dimensions cannot be assumed to hold for all parts of the country.

ROUGH-EDGE or FLITCH shall embrace all sizes one inch and up in thickness by eight inches and up in width, sawed on two sides only. For example: 1, 1½, 2, 3, 4 and up thick, by 8 and up wide, sawed on two sides only.

SQUARE-EDGED INSPECTION.

SCANTLING shall be free from injurious shakes, unsound knots, or knots to impair strength; sap, no objection.

PLANK shall be free from unsound knots, wane through or round shakes; sap, no objection.

DIMENSION SIZES.—Sap, no objection; no wane edges, no shakes to show on outside of stick. All stock to be well and truly manufactured, full to sizes, and saw-butted.

MERCHANTABLE INSPECTION.

SCANTLING shall show three corners heart free from injurious shakes or unsound knots.

PLANK, nine inches and under wide shall show one heart face and two-thirds heart on opposite side, over nine inches wide shall show two-thirds heart on both sides, all free from round or through shakes, large or unsound knots.

DIMENSION SIZES.—All square lumber shall show two-thirds heart on two sides, and not less than one-half heart on two other sides. Other sizes shall show two-thirds heart on faces and show heart two thirds of the length on edges, excepting where the width exceeds the thickness by three inches or over; then it shall show heart on the edges for one half its length.

STEPPING shall show three corners heart, free from shakes and all knots exceeding half an inch in diameter and not more than six in a board.

ROUGH-EDGE or FLITCH shall be sawed from good heart timber, and shall be measured in the middle on the narrow face, free from injurious shakes or unsound knots. All stock to be well and truly manufactured, full to size, and saw-butted.

PRIME INSPECTION.

SCANTLING shall show three corners heart, and not to exceed one inch of sap on fourth corner, measured diagonally, free from heart, shakes, large or unsound knots.

PLANK shall show one entire heart face, on opposite face not exceeding one sixth its width of sap on each corner, free from

unsound knots. Through or round shakes; sap to be measured on face.

DIMENSION SIZES.—On all square sizes the sap on each corner shall not exceed one sixth the width of the face. When the width does not exceed the thickness by three inches, to show half heart on narrow faces the entire length; sap on wide faces to be measured as on square sizes.

ROUGH-EDGE or FLITCH shall be measured in the middle or narrow face inside of sap, free from shakes or unsound knots.

CLEAR INSPECTION.

SCANTLING and PLANK shall be free of sap, large knots, or other defects.

DIMENSION SIZES shall be free from sap, large or unsound knots. shakes through or round.

DESIGNATIONS OF THE TRADE.

RESAWED LUMBER.—Lumber sawn on four sides.

ROUGH-EDGE or FLITCH.—Lumber sawn on two sides.

TIMBER.—Hewn only.

MERCHANTABLE FLOORING.

1 in. and 1¼ in. in thickness and from 4 to 6 in. in width, shall show one face free from sap, and two-thirds heart the entire length on the opposite face. Shall be free from rot, split, shakes, and unsound knots. Sound knots to be allowed as follows, viz.: Two knots in boards under 10 ft. long; three knots in boards 16 ft. long and over, of not over 1 in. in diameter, or six knots of not over ½ in. in diameter.

MERCHANTABLE FLOORING-PLANK.

1½ to 3 in. in thickness and 5 to 10 in. in width shall show one face free from sap, except on each edge of the face; ½ in. of sap shall be allowed and two-thirds heart on opposite face. Free from rot, split, shakes, unsound knots, and knots exceeding 1¼ in. in diameter.

MERCHANTABLE WIDE BOARDS AND PLANK.

1 to 2 in. in thickness and 10 to 14 in. in width shall show one face free from sap, and two-thirds heart entire length on opposite

face. Free from rot, through shakes, splits, and unsound knots; six sound knots of 1 in. and under in diameter, or three of 1½ in. in diameter, to be allowed in any place.

Prime Wide Boards and Plank.

1 to 2 in. in thickness and 10 to 14 in. in width shall show one face and one edge free from sap, and two-thirds heart on the other face; free from rot, shakes, splits, and knots.

Merchantable Sidings.

1 in., 1¼ in., and 1½ in. in thickness and 4 in. and over in width. Sap shall be allowed on the face, or best side (regardless of sap on the opposite face), as follows: ½ in. on one edge on boards 7 in. and under in width, and ½ in. on each edge of boards over 7 in. wide. Must be free from through shakes, rots, splits, and unsound knots; and on the face side the following allowance for knots shall be made, viz.: Three sound knots not exceeding 1 in. in diameter in boards under 14 ft. long; four sound knots not exceeding 1 in. in diameter in boards 14 ft. long and over, or six sound knots not exceeding ½ in. in diameter in boards of any length. In the measurement of boards, flooring, and sidings 1½ in. and under in thickness the fractions of a foot in contents less than nine twelfths shall be thrown off; six twelfths and over shall be counted as a foot. In the measurement of merchantable sidings, as to widths, they shall be measured whole and half inch only. For example: 4 in., 4½ in., 5 in., 5½ in., 6 in., 6½ in., etc., wide.

Kiln-dried Sidings and Flooring are inspected in the New York market as follows: *Kiln-dried Saps*, 1 in. and 1½ in. in thickness, 3 in. and up wide, 12 to 18 ft. long, small percentage 10 and 11 ft., 90 per cent shall be free from knots and stain on one face, 10 per cent may have stain defects or a few sound knots.

Rough or Dressed Flooring, clear heart face rift or flat grain, to be free of knots, sap, or pitch-streaks on face side; No. 1 flooring to be free of knots on face, but admitting bright sap.

Inspection of White Pine, Spruce, etc.

White Pine.—White-pine plank and boards will frequently deteriorate in quality during the process of seasoning, or, more correctly speaking, imperfections which are entirely hidden when the wood is green become visible after it has dried out.

White pine is graded into three qualities, viz., *panel*, *common*, and *cullings*. All boards and plank that shall not have more than three small sound knots, not more than half an inch in diameter, without sap or shake or any other defect or being free from knots and not having on an average more run of sap than half the thickness of the board or plank shall be deemed and counted as *panel*. All boards and plank that shall not contain more than three—round—knots, not more than one inch in diameter, and not more run of sap than half the thickness of the board or plank, shall be deemed and counted as *common*. A split in the end of a board or plank nearly straight and not over two feet in length shall not condemn it to an inferior grade; the split shall not vary more than half an inch to a foot from a straight line. All boards or plank that are rotten, worm-eaten, wind-shaken, or otherwise defective are classed as *cullings*.

Spruce requires careful examination. The adhesion of the annual rings is very slight, and boards taken from the outside of the tree are liable to curl up and splinter when dried; boards cut from saplings are subject to excessive shrinkage. Reject all waney pieces and those with knots and sap.

Hardwood Lumber Grades.

The Boston law for the inspection of black walnut and cherry, ash, oak, poplar, and butternut, requires that the woods be divided into three grades, number one, number two, and culls.

Number One includes all boards, plank, or joist that are free from rot and shakes, and nearly free from knots, sap, and bad taper; the knots must be small and sound, and so few that they would not cause waste for the best kind of work. A split in a board or plank if parallel with the edge of a piece is classed number one.

Number Two includes all other descriptions except when one third is worthless. When a board, plank, or joist contains sap, knots, splits, or any other imperfections combined, making less than one third of a piece unfit for good work, and only fit

for ordinary purposes, it is number two; when one third is worthless it is a cull or refuse.

REFUSE or CULL hardwood includes all boards, planks, or joists that are manufactured badly, by being sawed in diamond-shape, smaller in one part than in another, split at both ends, or with splits not parallel, large and bad knots, worm-holes, sap, rot, shakes, or any imperfections which would cause a piece of lumber to be one third worthless or waste.

All hardwoods are measured from six inches up; and all lumber sawed thin is inspected the same as if of proper thickness, but is classed as thin, and sold at the price of thin lumber.

THE REGULAR SIZES are $\frac{5}{8}$-, 1-, $1\frac{1}{4}$-, $1\frac{1}{2}$-, 2-, $2\frac{1}{2}$-, 3-, 4-inch, and up, by even inches. The regular lengths are 12, 14, and 16 feet; shorter than 12 feet does not command full market price.

Inspection of Quartered Oak and Yellow Pine.

OAK for trimming, finishing, or flooring is *rift-sawed* or *quartered*, that is, sawed with two cuts at right angles with each other, and through the centre of the log, all subsequent cuts being made as nearly as possible on radial lines.

Oak is distinguished from all other woods by the "silver grain" or medullary rays consisting of small bundles of fibres, which shoot out laterally from the centre of the trunk, passing through the annual rings toward the bark. By quartering the log these fibres are divided nearly or quite in the direction of their course, and show on the surface of the boards as flecks or irregular silvery streaks upon a ground of fine parallel lines formed by the section of the annual rings. If, on the contrary, the log is sawed into parallel slices in the ordinary manner, the middle slice will exhibit the silver grain, as will also one or two on each side of it. Further from the centre the medullary rays will be divided almost transversely, appearing on the cut surface as nearly imperceptible lines or dashes, while the sections of the annual rings will grow broader and broader, showing, since the sap tubes of oak are quite large, as a coarse, rough figure, completely different in appearance from the delicate and silvery grain, and liable to a dingy discoloration from the entrance of dust and dirt into the exposed pores. Some varieties of oak, sawed in the ordinary way, often appear *brashy*, or of a very coarse texture, with short fibres which break away easily.

The manner in which the log is sawn affects also its disposition

to warp and curl, which in badly cut oak is very strong. The inner portions of the tree are compressed and hardened by age, so that there is a gradual diminution of density toward the circumference, which is occupied by the soft and spongy sap-wood. The less compact substance naturally shrinks more in drying than that which is nearer the interior of the log, but with boards whose surfaces follow the radial lines the movements caused by dryness or damp are all in the planes of these surfaces, and although the board varies in width, it has no tendency to warp. Those boards, on the contrary, which are cut in lines parallel with the diameter of the log have one surface which looks toward the bark of the tree and the other toward the heart, and the fibres on one side are therefore slightly softer than on the other, and will shrink more, curling the piece outward with a force proportioned to its thickness.

By keeping constantly in mind these properties of oak, which belong in some degree to all kinds of timber, many annoying defects in hardwood finish may be avoided.

YELLOW PINE for floors and finishing is cut, like quartered oak, on radial lines. These may be recognized by the figure, consisting of fine parallel lines in place of the broad mottlings produced by a cut tangent to the annual rings. Hard-pine boards of the latter kind are very liable to splinter and must be rejected. Hard-pine boards containing large streaks of dark turpentine should be rejected, as the turpentine soon crumbles away.

VI. Metals.

The metals used in construction are iron, copper, lead, tin, zinc, and some of their alloys.

These metals are not found to any great extent in the pure metallic state, but chiefly in the form of oxides, carbonates, or sulphides called "ores."

The ores are broken up, and separated from the earthy matters adhering to them, by stamping or crushing in mills and by washing with a stream of water, which carries away the lighter impurities, leaving the ore, which is then said to be "dressed."

The extraction of the metal from the ore is effected by various processes, generally by smelting, the ore being mixed with a flux; i.e., a mineral substance which will readily combine with the impurities of the ore is placed in a suitable furnace and subjected to intense heat, upon which the metal sinks down in a fluid state, while the impurities combine with the flux and run off in a light and fusible slag.

Iron.

Iron is extracted from its ores by smelting in a blast-furnace, using either a "cold blast," i. e., a blast at ordinary temperature, or a "hot blast." In this the air is raised to a temperature of from 800° to 1400° F. before being forced into the furnace. The intense heat developed causes fusion of the substances. The molten metal sinks to the bottom and over this is collected a glassy refuse composed of the lighter and more fusible impurities. This is called "slag." The slag is drawn off, run into iron cars, and hauled to the dumping-ground.

When a considerable quantity of molten iron has collected the furnace is tapped, and the iron is run into a long channel formed in sand, having smaller channels on each side. These small channels are 3 or 4 inches deep and 2 to 2½ feet long. The channels are called the sow and her pigs; hence the bars produced are called "pig iron."

It is generally considered that the cold-blast irons are superior to the hot-blast. The hot blast, while saving fuel and producing a larger yield, also causes the iron to combine with a larger quantity of impurities.

Pig Iron is classed under several heads, as *Foundry Pig*, *Bessemer Pig*, and *Forge Pig*. These classes are graded according to the character of the fracture, the number of grades varying in different localities. In Eastern Pennsylvania the principal grades recognized are known as *No.* 1 and *No.* 2 *Foundry*, *No.* 3 *Gray Forge*, *No.* 4 *Mottled*, and *No.* 5 *White*. Intermediate grades are sometimes made, as *No.* 2*X* between No. 1 and No. 2, and special names are given to irons more highly silicized than No. 1, as *No.* 1*X*, *Silver Gray*, and *Soft*. Charcoal foundry pig iron is graded by numbers 1 to 5, but the quality is very different from the corresponding numbers in anthracite and coke pig. Southern coke pig iron is graded into ten or more grades, as follows, beginning with the highest in silicon: *Nos.* 1 *and* 2 *Silvery*, *Nos.* 1 *and* 2 *Soft*, all containing over 3 per cent of silicon; *Nos.* 1, 2, *and* 3 *Foundry*, respectively about 2.75 per cent, 2.5 per cent, and 2 per cent silicon; *No.* 1 *Mill, or Foundry Forge*, *No.* 2, *or Gray Forge; mottled, and white.*

TABLE 8.

COMPOSITION OF PIG IRON.

The following analyses show the composition of the five standard grades of Northern foundry and mill pig irons:

	No. 1 Gray.	No. 2 Gray.	No. 3 Gray.	No. 4 Mottled.	No. 4 B.	No. 5 White.
Iron	92.37	92.31	94.66	94.48	94.08	94.68
Graphitic carbon	3.52	2.99	2.50	2.02	2.02	....
Combined carbon	.13	.37	1.52	1.98	1.43	3.83
Silicon	2.44	2.52	.72	.56	.92	.41
Phosphorus	1.25	1.08	.26	.19	.04	.04
Sulphur	.02	.02	trace	.08	.04	.02
Manganese	.28	.72	.34	.67	2.02	.98
	Used exclusively in the foundry.		Rolling-mill or foundry.	Rolling-mill.		

IMPURITIES IN PIG IRON.

The various ores and the mineral fuels used in smelting frequently contain substances which injure the quality of the respective metals produced from the pig iron unless eliminated in subsequent processes.

The following are some of the principal impurities:

PHOSPHORUS is very readily taken up during the smelting process, and is one of the worst impurities it can contain.

Cast iron is hardened by it, but is made more readily fusible; shrinkage is decreased and fluidity increased. Its tenacity is reduced.

Wrought iron is injured by it in proportion to the quantity present.

$\frac{1}{10}$ per cent does not reduce the strength, but improves its welding capacity.

$\frac{3}{10}$ per cent makes it harder, but not weaker.

$\frac{5}{10}$ per cent makes it "cold-short."

1 per cent makes it very brittle, and unfit for any but special purposes.

Steel is injured by a very minute proportion.

SULPHUR is derived from the pyrites in the ore and coal.

In *cast iron* it tends to produce the mottled and white varieties; in general its influence is to drive out carbon and silicon, to increase chill and shrinkage, and to decrease strength.

In *wrought iron* three tenths per cent produces "Red-shortness.

In *steel* one tenth per cent produces "Red-shortness"; more than two tenths per cent unfits it for forging, but makes it more fluid.

MANGANESE. In *cast iron* it tends to produce the white variety; it increases the holding capacity for carbon, reduces plasticity, and increases brittleness and shrinkage.

Manganese decreases the magnetism of iron. This characteristic increases with the percentage present. When 25 per cent is present the iron loses all its magnetism. This peculiarity has been made use of by French metallurgists to draw a clear line between *spiegel* and *ferro*-manganese. When the pig iron contains less than 25 per cent of manganese it is classed as *spiegel*, and when more than 25 per cent it is classified as *ferro-manganese*. For this reason manganese iron has to be avoided in castings of dynamo-fields and other pieces belonging to electric machinery.

When the quantity of manganese is under 40 per cent, with the remainder mostly iron, and silicon not over 0.50 per cent, the alloy is called *Spiegeleisen*, and the fracture will show flat reflecting surfaces, from which it takes its name,

A little manganese is an excellent antidote against sulphur in the furnace.

In *wrought iron and steel* it counteracts red-shortness. Its presence is essential in the manufacture of Bessemer steel, and in some other processes.

SILICON.—The effect produced by silicon in *cast iron* varies according to the physical properties of the original iron: in some it causes hardness and brittleness, and decreases shrinkage; a small percentage usually increases strength, high percentage decreases strength.

Wrought iron is rendered by it hard and brittle. To obtain good wrought iron the silicon must be removed as far as possible by repeatedly heating and working the iron.

Steel.—$\frac{1}{2000}$ part makes it cool and solidify without bubbling and agitation, more makes it brittle; $\frac{1}{8}$ per cent makes it unforgeable.

MATERIALS PRODUCED FROM PIG IRON.

By subjecting pig iron to various processes three varieties of material are produced, viz.: Cast Iron, Wrought Iron, Steel.

The great differences that exist between these materials depend chiefly upon the amount of carbon they respectively contain, the other substances present being generally regarded as impurities.

The percentage of carbon present in these materials and their several gradations is about as follows:

Cast iron	4.00	to	5.00	per	cent.
Malleable cast iron	0.88	"	1.52	"	"
Wrought iron	0.00	"	0.25	"	"
Soft steel			0.075	"	"
Mild steel	0.08	"	0.20	"	"
Hard steel	0.20	"	0.40	"	"
Tool steel	0.40	"	0.80	"	"
Draw-plate steel			3.30	"	"

Cast Iron.

Cast iron is obtained by remelting the foundry pig iron and running it into moulds of the shape required.

In some cases the metal is run into the moulds direct from the blast-furnace, but in superior work it is generally specified that the cast iron is to be of the "second melting," that is, from pigs remelted in a cupola.

There are two principal varieties of cast iron, the *gray* and the *white*, differing in their chemical and physical characters; and between these two are several intermediate varieties, which resemble more or less the gray or the white as they approach nearer to one or the other.

Gray iron contains one per cent or less of carbon chemically combined, and from one to four per cent of carbon in the state of graphite mechanically mixed.

The gray iron is soft and tough, slightly malleable when cold, may be drilled, planed, or turned, melts at a lower heat than the white, being red when molten, remains fluid a long time, fills the mould readily, and gives fine sharp angles to the casting. The fracture is granular, of a gray color, with a metallic lustre.

White iron contains from two to five per cent of carbon in a state of chemical combination. It is hard, brittle, and sonorous, cannot be worked, is not easily melted, is white when fluid, thickens rapidly, and shows a white crystalline fracture, with a vitreous lustre.

The gray iron is most suitable for strength, the white for hardness.

The two varieties may be produced from the same ore under different conditions of temperature. The carbon requires to cool slowly in order to form graphite, and to exist as a separate material in the iron; rapidly cooled, the carbon remains chemically combined, thus producing white iron.

The term "chilling" irons is generally applied to those which if cooled slowly would be gray, but when cooled suddenly become white either to a depth sufficient for practical utilization (e. g., in car-wheels) or so far as to be detrimental. Many irons chill more or less in contact with the cold surface of the moulds in which they are cast, especially if they are thin. Sometimes this is a valuable quality, but for general foundry purposes it is desirable to have all parts of a casting an even gray.

The density and strength of cast iron is increased by repeated remelting up to about the twelfth time, after which it is decreased. The increase is the result of the gradual abstraction of the constituent carbon and the consequent approximation to wrought iron.

By prolonged fusion the tenacity is increased.

Both remelting and prolonged fusion may be carried too far; as the carbon is removed the iron becomes less fluid, fills the moulds less perfectly, and produces too hard and brittle a metal.

Properties of Cast Iron.

SPECIFIC GRAVITY, 6.85 to 7.48.

WEIGHT PER CUBIC FOOT, usually assumed at 450 lbs.

ATOMIC WEIGHT, 56.

HARDNESS, 4.57 to 33.51.

MELTING-POINT: Gray iron, 2012° to 2786° F.
White iron, 1922° to 2075° F.

SPECIFIC HEAT, .1298.

CONDUCTIVITY FOR HEAT, 11.9.

CONDUCTIVITY FOR ELECTRICITY, 12 to 14.8 (silver being 100).

EXPANSION AND CONTRACTION.—Expansion in bulk by heat, .0033; exposed to continued heat it becomes permanently expanded from $1\frac{1}{4}$ to 3 per cent of its length. A bar will contract or expand .000006173 of an inch, or $\frac{1}{162000}$ of its length for each degree of heat; between the extremes − 20° F. and + 120° F. it will contract or expand .0008642 of an inch, or the 1157th part of its length, equivalent to a strain of $4\frac{3}{4}$ tons per square inch.

CONTRACTION on cooling ranges from $\frac{1}{86}$th to $\frac{1}{98}$th of the length.

EXTENSION, $\frac{1}{5000}$ of its length per ton per square inch, or .000000107 of its length per pound of tension.

COMPRESSION per pound = .0000000804 of the length.

ELONGATION.—The elastic limit is not clearly defined, the elongation increasing faster than the increase of the loads from the beginning of the test. The modulus of elasticity is therefore variable, decreasing as the loads increase. The following results of a test by Prof. Lanza are an example;

TABLE 9.

CAST IRON: ELONGATION AND MODULUS OF ELASTICITY.

Pounds per Square Inch.	Elongation in 13.4 inches.	Sets in	Modulus of Elasticity.
1000	.0004	....	18,217,400
2000	.0013	....	16,777,700
3000	.0024	....	14,085,400
4000	.0036	....	13,101,200
5000	.0048	....	12,809,200
6000	.0061	.0000	12,319,300
8000	.0088	.0001	11,600,800
10000	.0119	.0001	10,930,500
12000	.016	.0007	9,714,200

SHRINKAGE.—The usual allowance for shrinkage is ⅛ inch per foot.

ULTIMATE STRENGTH.—Tensile, 9000 to 45.970 lbs. per sq. in.
Compressive, 80,000 to 174,120 lbs. per sq. in.
Shearing (mean), 24,000 lbs. per sq. in.
Torsion " 8,614 " " "
Transverse, 500 to 4,000 " " "

WORKING STRENGTH.—Tensile, 3,000 lbs. per sq. in.
Compressive, 80,000 " " "
Transverse, 600 " " "
Shearing, 6,000 " " "
Torsion, 5,000 " " "

TENACITY AT HIGH TEMPERATURES.—Cast iron appears to maintain its strength, with a tendency to increase until 900° F. is reached, beyond which temperature it gradually decreases. (Jas. E. Howard's Tests, *Iron Age*, April 10, 1890.)

Cast iron of average quality loses strength when heated above 120° F.; and it becomes insecure at the freezing-point. At a red heat its normal strength is reduced one third. (D. K. Clark.)

Notes on Founding.

Cast iron becomes more compact and sound by being cast under pressure; hence pipes, columns, and the like are stronger when cast in a vertical than in a horizontal position, and stronger still when provided with a *head*, or additional column of iron, whose weight serves to compress the mass of iron in the mould below it. The air-bubbles ascend and collect in the head, which is broken off when the casting is cool.

"Blow-holes" and "honeycomb" are produced by confined air and render castings defective.

Cavities and flaws caused by unequal contraction during cooling, and the collection of foundry dirt and other impurities, are frequent sources of weakness.

In column and pipe castings a common defect is unevenness of thickness. This may be detected either by drilling small holes along the sides, or by a careful application of the calipers. If one side is much thicker than the other the thin side cools first and is consequently subjected, during the cooling of the thick side, to strains frequently severe enough to bend the casting and produce injury. Columns or pipes cast upon their sides suffer from this imperfection by the displacement of the core. Columns or pipes taken from the mould too quickly are apt to be bent in the handling.

Unequal contraction of the metal in cooling frequently causes strains which produce rupture especially in columns and lug castings.

When castings are of such length as to make it necessary to pour the metal into the mould from both ends, it frequently occurs that the iron becomes too much chilled to properly mix and unite, thus forming weak seams, called "cold-shuts."

Castings should be covered up and allowed to cool as slowly as possible. They should remain in the sand until cool. If they are removed from the mould in a red-hot state, the metal is liable to injury from too rapid and irregular cooling.

The unequal cooling and consequent injury caused by great and sudden differences in the thickness of parts of a casting are sometimes avoided by uncovering the thick parts so that they may cool more quickly.

Inspection of Cast Iron.

The appearance of good cast iron for structural purposes should show on the outer surface a smooth, clear, and continuous skin, with regular face and sharp angles. When broken, the surface of the fracture should be of a light bluish-gray color and close-grained texture, with considerable metallic lustre; both color and texture should be uniform, except that near the skin the color may be somewhat lighter and the grain closer; if the fractured surface is *mottled*, either with patches of darker or lighter iron, or with crystalline patches, the casting will be unsafe, and it will be still more unsafe if it contains air-bubbles. The iron should be soft enough to be slightly indented by a blow of a hammer on the edge of the casting; if it is hard and brittle, fragments will be broken off.

Castings are tested for "honeycomb" by tapping with a hammer.

Blow- or sand-holes filled in with sand from the mould or purposely stopped with loam cause a dulness in the sound which leads to their detection.

In examining water-pipes and the castings connected therewith, see that the interior is free from *swells*, *scale*, and *blisters*. Test thickness with the calipers. Sound thoroughly with the hammer to discover flaws, air- or sand-holes. Examine the junction of the hubs or bells with the body for honeycomb. See that the hydraulic pressure required by the specifications is applied. While under pressure tap the pipe all over to discover flaws, etc. Inspect the weighing and marking of each piece.

Columns and posts are examined for cold-shuts, sand- and blow-holes; the thickness of the shaft in closed columns is tested by drilling a sufficient number of $\frac{3}{8}$-in. holes. The connections of lugs, brackets, capitals and bases require close examination to discover flaws, shrinkage cracks and blow-holes.

Test Bars.—The test-bars should be poured alternately before and after the casting is poured; there should be at least one test bar for each 2000 lbs. of castings, or such number as the specifications require.

The test-bars are usually 3 in. wide by 1 in. thick, and either 14 or 26 in. long; they are placed on supports 12 or 24 in. apart, narrow side up, and loaded in the centre until broken. Note the deflection and breaking weight.

The bars for testing tensile strength are usually turned down on a lathe in order to remove the rough exterior scale and enable the diameter to be carefully measured.

TABLE 10.

CAST IRON. WEIGHT OF PLATES, ROUND AND SQUARE BARS.

At 450 lbs. per cubic foot a pound contains 3.84 cubic inches, a ton 5 cubic feet, and a cubic inch weighs .2604 lb.

Malleable Cast Iron.

Malleable cast iron is the name given to castings made of ordinary cast iron which have been subjected to a process of decarbonization, which results in the production of a crude wrought iron.

The castings are made in the usual way, and are then embedded in oxide of iron, usually of hematite ore, or in peroxide of manganese, and exposed to a full red heat for a sufficient length of time to insure the nearly complete removal of the carbon. This decarbonization is conducted in cast-iron boxes, in which the articles, if small, are packed in alternate layers with the decarbonizing material. The largest pieces require the longest time. The fire is quickly raised to the maximum temperature, but at the close of the process the furnace is cooled very slowly. The operation requires from three to five days with small castings, and may take two weeks for large pieces.

Strength of Malleable Cast Iron.

Tensile—25,000 to 35,000 lbs. per square inch.
Elongation—1 to 2 per cent in 4 inches.
Elastic Limit—15,000 to 21,000.

Inspection of Malleable Iron Castings.

The fracture should be fine-grained and uniform, and be free from blow-holes; the centre should appear almost as dark as burnt iron.

Tests should be made at the foundry prior to shipment, extra castings from which to cut test pieces being furnished at the rate of at least two for every 2000 lbs. of product.

All test-pieces should be cut, prepared, and tested under the eye of the inspector.

Should the average of three tests show a less strength than required by the specifications, a repetition of the tests will be at the option of the inspector.

Each casting requires to be closely examined for shrinkage cracks, blow-holes, large ridges at partings, and flaws on edges. Castings that are incorrect in dimensions or warped should be rejected.

Wrought Iron.

Wrought iron in its perfect condition is simply pure iron. It falls short of that perfect condition to a greater or less extent owing to the presence of impurities.

Wrought iron may be produced direct from the ore, but is commonly obtained from *forge pig* or the harder varieties of pig iron.

In the manufacture of "refined iron" or "merchant-bar iron," the object to be attained is the removal of the carbon, phosphorus, silicon, and other impurities.

The refining process is performed as follows:

I. PUDDLING.—The pig iron mixed with oxidizing substances, such as hematite ore, limestone, salt, etc., is placed in a reverberatory furnace and melted, the molten metal being stirred and agitated with a rake or "rabble." The admission of air during the stirring oxidizes the carbon and silicon, which pass off in the slag. As the iron becomes purer it becomes less fusible and stiffens. It is then worked by the puddler into lumps or balls called *puddle-balls* or *blooms*, weighing about 75 lbs. each. These balls are removed from the furnace and placed either under a tilt-hammer or squeezer to be *shingled*, that is, to have the cinder forced out, and to be formed into suitable shape for rolling into *muck-bars*.

II. ROLLING MUCK-BARS.—The shingled iron is next passed through the *muck rolls* and reduced to bars from 3 to 4 in. wide, $\frac{3}{4}$ to 1 in. thick, and 10 to 12 ft. long, and very rough in appearance. These constitute what are known as "muck-bars" or "puddled bars," or the lowest grade of iron.

The muck-bars are cut up into lengths of 6 or 7 ft., depending upon the size of the piece to be rolled, placed in an oven with waste scrap, reheated, and passed through the rolls. The bars so produced are called *refined iron*.

For *Double Refined Iron* the bars of refined iron are cut up, piled, reheated, and again rolled into flat bars. These are repiled and rolled into final shapes. This iron is much stronger and more homogeneous than ordinary refined iron.

After the iron is rolled to final shape it is run out on a series of skids called the *hot-bed*, where it is allowed to cool. From here it goes to the straightening-machine. This may either be a gag-press or a train of rolls, three below and two above. The latter is much the better, producing straighter bars with less injury to the material.

The heating and rolling several times improves the quality of the iron, but it will not stand too many. The fifth reheating seems to be the limit.

After coming from the straightening-rolls the material is marked and sheared, then inspected, and each piece marked with its true dimensions in white-lead paint.

Wrought iron is distinguished from the other varieties of iron by the property of *welding;* two pieces, if raised nearly to a white heat and pressed or hammered firmly together, adhere so as to form one piece. In all operations of rolling or forging iron of which welding forms a part, it is essential that the surfaces to be welded should be brought into close contact, and should be perfectly clean and free from oxide of iron, cinder, and all foreign matter.

TABLE 11.

COMPOSITION OF WROUGHT IRON.

The following analyses show the composition of some standard brands of wrought iron :

	I.	II.	III.	IV.	V.	VI.
Sulphur	trace	0.001	0.008	0.005	0.004	0.007
Phosphorus	0.084	0.035	0.231	0.291	0.067	0.169
Silicon	0.105	0.028	0.156	0.321	0.065	0.154
Carbon	0.512	0.066	0 015	0.051	0.045	0.042
Manganese	0.029	0 009	0.017	0.053	0.007	0.021
Slag	0.452	1.214	....	1.724	1.168	....
Tensile strength	66.598	54.363	52.764	51.754	51.134	50.765

Properties of Wrought Iron.

SPECIFIC GRAVITY, 7.4 to 7.9.

WEIGHT PER CUBIC FOOT, 480 to 487, usually taken at 480.

ATOMIC WEIGHT, 56.

MELTING-POINT, 2732° to 3000° F.

SPECIFIC HEAT, .1138.

CONDUCTIVITY of heat, 11.9; of electricity, 12 to 14.8 (silver being 100).

EXPANSION BY HEAT in bulk between 32° and 212° F. = .0035. Bars will expand or contract .000006614 of an inch, or the 151,200th part of their length, or about ⅛ inch in 1562 feet for each degree of heat. Between the extremes −20° F. and +120° F.

a bar will expand, or contract .000926, or the 1080th part of its length, a variation equivalent to a strain of 9¼ tons per square inch of section. For a variation in temperature of 125° a bar 100 feet long will expand or contract 1.029 inches; with a variation of 15° the expansion or contraction is about $\frac{1}{10000}$ of the length, and the strain thus induced if the ends are held rigidly fixed will be about 1 ton per square inch.

CONTRACTION.—When a bar of wrought iron is heated to redness and quenched in water it becomes permanently shorter than before.

EXTENSION per pound of tensile force = .0000000357 of the length, or about 1 inch in 1000 feet, or ⅛ inch in 125 feet for every ton of tensile strain per square inch up to the elastic limit.

ULTIMATE STRENGTH.

Tensile	30,000 to 70,000	pounds
Compressive	40,000 to 127,720	"
Shearing	40,000	"

WORKING STRENGTH.

Tensile	10,000 to 15,000	lbs. per sq. in.
Compressive	36,000	" " " "
Shearing	6000 to 9000	" " " "

STRENGTH OF WELDS.

	Tie-bars. Pounds.	Plates. Pounds.	Chains. Pounds.
Strength of solid bar	48,201 to 57,065	44,851 to 47,481	49,122 to 57,875
Strength of weld	17,816 to 44,586	26,442 to 38,931	39,575 to 48,824

Welding heat is about 2738° F.

ELONGATION ranges from 5 to 30 per cent of the original length.

REDUCTION OF AREA AT FRACTURE varies from 55 to 25 per cent.

MODULUS OF ELASTICITY, 22,000,000 to 29,000,000.

TENACITY AT HIGH TEMPERATURES.—The strength of wrought iron increases with temperature from 0° up to a maximum at from 400° to 600°F., the increase being from 8000 to 10,000 pounds per square inch, and then decreases steadily till a strength of only 6000 lbs. per square inch is shown at 1500° F.

Mill Inspection of Wrought Iron.

In the mill inspection of wrought iron no tests can be made before the material is rolled.

With the same kind of muck-bar and the same kind of scrap, each pile will generally be found to differ from all the others; and because of this difference it is necessary, in order to ascertain its fitness for a specific purpose, to subject it to careful and accurate tests. The following are the usual requirements: It must be tough, ductile, and fibrous, free from cinder-pockets, flaws, buckles, blisters, and cracks along the edges.

Toughness is indicated by a fine, close, and uniform fibrous structure, free from all appearance of crystallization, with a clear bluish-gray color and silky lustre on a torn surface where the fibres are exposed.

BADLY REFINED IRON is indicated by coarse crystals, blotches of color, loose, open, and blackish fibres. Flaws in the fractured surface denote that the piling and welding processes were imperfectly carried out.

GOOD IRON is indicated by small crystals of a uniform size and color and fine, close, silky fibres. Good iron is readily heated, is soft under the hammer, and throws out few sparks.

A soft, tough iron, if broken gradually gives long, silky fibres of leaden-gray hue, which twist together and cohere before breaking; broken rapidly the fracture will have a crystalline appearance.

Iron if brought to a white heat is injured if it be not at the same time hammered or rolled.

COLD-SHORT IRON.—Iron containing phosphorus is brittle when cold, and will crack if bent double. Cold-short iron is indicated by either a fine grain and steely appearance, or a coarse grain with bright crystalline fracture, and discolored spots.

RED-SHORT IRON.—Iron containing sulphur, copper, arsenic, and other impurities will crack when bent at a red heat, but has considerable tenacity when cold. It cannot be welded. Such iron is termed "red-short." Cracks on the edge of a bar are indications of red-short iron.

Tests for Wrought Iron.

BENDING TEST (COLD).—Good iron should bend cold 180 degrees around a curve whose diameter is twice the thickness of the piece for bar iron and three times the thickness for plates and shapes.

BENDING TEST (HOT).—Iron which is to be worked hot must be capable of bending sharply to a right angle at a working heat without sign of fracture.

NICKING AND BENDING.—Specimens upon being nicked on one side and bent should show a fracture nearly all fibrous.

RIVET iron should be tough and soft, and be capable of bending cold until the sides are in close contact without sign of fracture on the convex side of the curve.

The tensile strength, limit of elasticity, and ductility are determined from test-pieces cut from the full-sized bar. The number and size of the test-pieces will be governed by the specification. Test-pieces are usually cut about 18 inches long, 1 inch in width at the reduced portion, and of the same thickness as the piece from which it was taken. The area of cross-section ought not be less than half a square inch.

Iron heated and suddenly cooled in water is hardened, and the breaking strain (if gradually applied) is increased, but it is more likely to snap suddenly. If heated and allowed to cool gradually, it is softened, and its breaking strain is reduced.

Table 12.

WEIGHT OF FLAT BAR IRON PER LINEAL FOOT.

At 480 lbs. per cubic foot. For steel add 1/48.

Breadth, in inches.	Thickness, in Fractions of Inches.										
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16
1	0.208	0.417	0.625	0.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29
1⅛	0.234	0.469	0.703	0.938	1.17	1.41	1.64	1.87	2.11	2.34	2.58
1¼	0.260	0.521	0.781	1.040	1.30	1.56	1.82	2.08	2.34	2.60	2.86
1⅜	0.286	0.573	0.859	1.150	1.43	1.72	2.01	2.29	2.58	2.86	3.15
1½	0.313	0.625	0.938	1.250	1.56	1.88	2.19	2.50	2.81	3.13	3.44
1⅝	0.339	0.677	1.020	1.360	1.69	2.03	2.37	2.71	3.05	3.39	3.73
1¾	0.365	0.729	1.090	1.460	1.82	2.19	2.55	2.92	3.28	3.65	4.01
1⅞	0.391	0.781	1.170	1.560	1.95	2.34	2.73	3.12	3.51	3.91	4.30
2	0.417	0.833	1.250	1.670	2.08	2.50	2.92	3.33	3.75	4.17	4.58
2⅛	0.443	0.886	1.330	1.770	2.21	2.65	3.10	3.54	3.98	4.43	4.87
2¼	0.469	0.938	1.410	1.880	2.34	2.81	3.28	3.75	4.22	4.69	5.16
2⅜	0.495	0.990	1.480	1.980	2.47	2.97	3.46	3.96	4.46	4.95	5.44
2½	0.521	1.040	1.560	2.080	2.60	3.13	3.65	4.17	4.69	5.21	5.73
2⅝	0.547	1.090	1.640	2.190	2.73	3.28	3.83	4.38	4.92	5.47	6.02
2¾	0.573	1.150	1.720	2.290	2.86	3.44	4.01	4.58	5.16	5.73	6.30
2⅞	0.599	1.200	1.800	2.400	3.00	3.60	4.20	4.79	5.39	5.99	6.59
3	0.625	1.250	1.880	2.500	3.13	3.75	4.38	5.00	5.63	6.25	6.88
3¼	0.677	1.350	2.030	2.710	3.39	4.06	4.74	5.42	6.09	6.77	7.45
3½	0.729	1.460	2.190	2.920	3.65	4.38	5.10	5.83	6.56	7.29	8.02
3¾	0.781	1.560	2.340	3.130	3.91	4.69	5.47	6.25	7.03	7.81	8.59
4	0.833	1.670	2.500	3.330	4.17	5.00	5.83	6.67	7.50	8.33	9.17
4¼	0.885	1.770	2.660	3.540	4.43	5.31	6.20	7.08	7.97	8.85	9.74
4½	0.938	1.880	2.810	3.750	4.69	5.63	6.56	7.50	8.44	9.38	10.31
4¾	0.990	1.980	2.970	3.960	4.95	5.94	6.93	7.92	8.91	9.90	10.89
5	1.042	2.080	3.130	4.170	5.21	6.25	7.29	8.33	9.38	10.42	11.46
5¼	1.090	2.190	3.280	4.380	5.47	6.56	7.66	8.75	9.84	10.94	12.03
5½	1.150	2.290	3.440	4.580	5.73	6.88	8.02	9.17	10.31	11.46	12.60
5¾	1.200	2.400	3.590	4.790	5.99	7.19	8.39	9.58	10.78	11.98	13.18
6	1.250	2.500	3.750	5.000	6.25	7.50	8.75	10.00	11.25	12.50	13.75
6¼	1.300	2.600	3.910	5.210	6.51	7.81	9.11	10.42	11.72	13.02	14.32
6½	1.350	2.710	4.060	5.420	6.77	8.13	9.48	10.83	12.19	13.54	14.90
6¾	1.410	2.810	4.220	5.630	7.03	8.44	9.84	11.25	12.66	14.06	15.47
7	1.460	2.920	4.380	5.830	7.29	8.75	10.21	11.67	13.13	14.58	16.04
7¼	1.510	3.020	4.530	6.040	7.55	9.06	10.57	12.08	13.59	15.10	16.61
7½	1.560	3.130	4.690	6.250	7.81	9.38	10.94	12.50	14.06	15.63	17.19
7¾	1.610	3.230	4.840	6.460	8.07	9.69	11.30	12.92	14.53	16.15	17.76
8	1.670	3.330	5.000	6.670	8.33	10.00	11.67	13.33	15.00	16.67	18.33
8¼	1.720	3.440	5.160	6.880	8.59	10.31	12.03	13.75	15.47	17.19	18.91
8½	1.770	3.540	5.310	7.080	8.85	10.63	12.40	14.17	15.94	17.71	19.48
8¾	1.820	3.650	5.470	7.290	9.11	10.94	12.76	14.58	16.41	18.23	20.05
9	1.880	3.750	5.630	7.500	9.38	11.25	13.13	15.00	16.88	18.75	20.63
9¼	1.930	3.850	5.780	7.710	9.64	11.56	13.49	15.42	17.34	19.27	21.20
9½	1.980	3.960	5.940	7.920	9.90	11.88	13.85	15.83	17.81	19.79	21.77
9¾	2.030	4.060	6.090	8.130	10.16	12.19	14.22	16.25	18.28	20.31	22.34
10	2.080	4.170	6.250	8.330	10.42	12.50	14.58	16.67	18.75	20.83	22.92
10¼	2.140	4.270	6.410	8.540	10.68	12.81	14.95	17.08	19.22	21.35	23.49
10½	2.190	4.380	6.560	8.750	10.94	13.13	15.31	17.50	19.69	21.88	24.06
10¾	2.240	4.480	6.720	8.960	11.20	13.44	15.68	17.92	20.16	22.40	24.64
11	2.290	4.580	6.880	9.170	11.46	13.75	16.04	18.33	20.63	22.92	25.21
11¼	2.340	4.690	7.030	9.380	11.72	14.06	16.41	18.75	21.09	23.44	25.78
11½	2.400	4.790	7.190	9.580	11.98	14.38	16.77	19.17	21.56	23.96	26.35
11¾	2.450	4.900	7.340	9.790	12.24	14.69	17.14	19.58	22.03	24.48	26.93
12	2.500	5.000	7.500	10.000	12.50	15.00	17.50	20.00	22.50	25.00	27.50

WEIGHT OF FLAT BAR IRON PER LINEAL FOOT. (*Continued.*)

Breadth, in inches.	Thickness, in Fractions of Inches.										
	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8
1	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.37	4.58
1 1/8	2.81	3.05	3.28	3.52	3.75	3.98	4.22	4.45	4.69	4.92	5.16
1 1/4	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47	5.73
1 3/8	3.44	3.72	4.01	4.30	4.58	4.87	5.16	5.44	5.73	6.02	6.30
1 1/2	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88
1 5/8	4.06	4.40	4.74	5.08	5.42	5.75	6.09	6.43	6.77	7.11	7.45
1 3/4	4.38	4.74	5.10	5.47	5.83	6.20	6.56	6.93	7.29	7.66	8.02
1 7/8	4.69	5.08	5.47	5.86	6.25	6.64	7.03	7.42	7.81	8.20	8.59
2	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.92	8.33	8.75	9.17
2 1/8	5.31	5.75	6.20	6.64	7.08	7.52	7.97	8.41	8.85	9.30	9.74
2 1/4	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.91	9.38	9.84	10.31
2 3/8	5.94	6.43	6.93	7.42	7.92	8.41	8.91	9.40	9.90	10.39	10.89
2 1/2	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.90	10.42	10.94	11.46
2 5/8	6.56	7.11	7.66	8.20	8.75	9.30	9.84	10.39	10.94	11.48	12.03
2 3/4	6.88	7.45	8.02	8.59	9.17	9.74	10.31	10.89	11.46	12.03	12.60
2 7/8	7.19	7.79	8.39	8.98	9.58	10.18	10.78	11.38	11.98	12.58	13.18
3	7.50	8.13	8.75	9.38	10.00	10.63	11.25	11.38	12.50	13.13	13.75
3 1/4	8.13	8.80	9.48	10.16	10.83	11.51	12.19	12.86	13.54	14.22	14.90
3 1/2	8.75	9.48	10.21	10.94	11.67	12.40	13.13	13.85	14.58	15.31	16.04
3 3/4	9.38	10.16	10.94	11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.19
4	10.00	10.83	11.67	12.50	13.33	14.17	15.00	15.83	16.67	17.50	18.33
4 1/4	10.63	11.51	12.40	13.28	14.17	15.05	15.94	16.82	17.71	18.59	19.43
4 1/2	11.25	12.19	13.13	14.06	15.00	15.94	16.88	17.81	18.75	19.69	20.63
4 3/4	11.88	12.86	13.85	14.84	15.83	16.82	17.81	18.80	19.79	20.78	21.77
5	12.50	13.54	14.58	15.63	16.67	17.71	18.75	19.79	20.83	21.88	22.92
5 1/4	13.13	14.22	15.31	16.41	17.50	18.59	19.69	20.78	21.88	22.97	24.06
5 1/2	13.75	14.90	16.04	17.19	18.33	19.48	20.63	21.77	22.92	24.06	25.21
5 3/4	14.38	15.57	16.77	17.97	19.17	20.36	21.56	22.76	23.96	25.16	26.35
6	15.00	16.25	17.50	18.75	20.00	21.25	22.50	23.75	25.00	26.25	27.50
6 1/4	15.63	16.93	18.23	19.53	20.83	22.14	23.44	24.74	26.04	27.34	28.65
6 1/2	16.25	17.60	18.96	20.31	21.67	23.02	24.38	25.73	27.08	28.44	29.79
6 3/4	16.88	18.28	19.69	21.09	22.50	23.91	25.31	26.72	28.13	29.53	30.94
7	17.50	18.96	20.42	21.88	23.33	24.79	26.25	27.71	29.17	30.62	32.08
7 1/4	18.13	19.64	21.15	22.66	24.17	25.68	27.19	28.70	30.21	31.72	33.23
7 1/2	18.75	20.31	21.88	23.44	25.00	26.56	28.13	29.69	31.25	32.81	34.38
7 3/4	19.38	20.99	22.60	24.22	25.83	27.45	29.06	30.68	32.29	33.91	35.52
8	20.00	21.67	23.33	25.00	26.67	28.33	30.00	31.67	33.33	35.00	36.67
8 1/4	20.63	22.34	24.06	25.78	27.50	29.22	30.94	32.66	34.38	36.09	37.81
8 1/2	21.25	23.02	24.79	26.56	28.33	30.10	31.88	33.65	35.42	37.19	38.96
8 3/4	21.88	23.70	25.52	27.34	29.17	30.99	32.81	34.64	36.46	38.28	40.10
9	22.50	24.38	26.25	28.13	30.00	31.88	33.75	35.63	37.50	39.38	41.25
9 1/4	23.13	25.05	26.98	28.91	30.83	32.76	34.69	36.61	38.54	40.47	42.40
9 1/2	23.75	25.73	27.71	29.69	31.67	33.65	35.63	37.60	39.58	41.56	43.54
9 3/4	24.38	26.41	28.44	30.47	32.50	34.53	36.56	38.59	40.63	42.66	44.69
10	25.00	27.08	29.17	31.25	33.33	35.42	37.50	39.58	41.67	43.75	45.83
10 1/4	25.62	27.76	29.90	32.03	34.17	36.30	38.44	40.57	42.71	44.84	46.98
10 1/2	26.25	28.44	30.63	32.81	35.00	37.19	39.38	41.56	43.75	45.94	48.13
10 3/4	26.88	29.11	31.35	33.59	35.83	38.07	40.31	42.55	44.79	47.03	49.27
11	27.50	29.79	32.08	34.38	36.67	38.96	41.25	43.54	45.83	48.13	50.42
11 1/4	28.13	30.47	32.81	35.16	37.50	39.84	42.19	44.53	46.88	49.22	51.56
11 1/2	28.75	31.15	33.54	35.94	38.33	40.73	43.13	45.52	47.92	50.31	52.71
11 3/4	29.38	31.82	34.27	36.72	39.17	41.61	44.06	46.51	48.96	51.41	53.85
12	30.00	32.50	35.00	37.50	40.00	42.50	45.00	47.50	50.00	52.50	55.00

TABLE 13.
WROUGHT IRON AND STEEL.—WEIGHT OF PLATES, ROUND AND SQUARE BARS.

Thickness or Diam. In.	Dec. of a Foot.	Wt. of a Sq. Ft. Lbs.	Wt. of a Square Bar 1 ft. long. Lbs.	Wt. of a Round Bar 1 ft. long. Lbs.	Wt. of Balls. Lbs.	Thickness or Diam. In.	Dec. of a Foot.	Wt. of a Sq. Ft. Lbs.	Wt. of a Sq. Bar 1 ft. long. Lbs.	Wt. of Round Bar 1 ft. long. Lbs.	
1/32	.0026	1 263	.0033	.0026		3⅛	.26		32.86	26	
1/16	.0052	2 526	.0132	.0104		¼	.27		35.57	27	
3/32	.0078	3 789	.0296	.0233	.0001	⅜	.28		38.37	30	
⅛	.0104	5 052	.0526	.0414	.0003	½	.29		41.26	32	
5/32	.0130	6 315	.0823	.0646	.0005	⅝	.30		44.28	34	
3/16	.0156	7 578	.1184	.0930	.0009	¾	.31		47.37	37	
7/32	.0182	8 841	.1612	.1266	.0015	⅞	.32		50.57	39	
¼	.0208	10 10	.2105	.1653	.0023	4	.33		53.89	42	
9/32	.0234	11 37	.2665	.2093	.0033	⅛	.34		57.31	45	
5/16	.0260	12 63	.3290	.2583	.0045	¼	.35		60.84	47	
11/32	.0287	13 89	.3980	.3126	.0060	⅜	.36		64 47	50	
⅜	.0313	15.16	.4736	.3720	.0078	½	.37		68 20	53	
13/32	.0339	16.42	.5558	.4365	.0098	⅝	.38		72 05	56	
7/16	.0365	17 68	.6446	.5063	.0123	¾	.39		75.99	59	
15/32	.0391	18.95	.7400	.5813	.0151	⅞	.40		80.05	62	
½	.0417	20 21	.8420	.6613	.0184	5	.41		84.20	66	
9/16	.0469	22.73	1.066	.8370	.0262	⅛	.42		88 47	69 48	19.75
⅝	.0521	25.26	1.316	1 033	.0359	¼	.43		92.83	72.91	21.26
11/16	.0573	27 79	1.592	1.250	.0478	⅜	.44		97 31	76 43	22.82
¾	.0625	30 31	1.895	1 488	.0620	½	.45		101 9	80.02	24 45
13/16	.0677	32 84	2.223	1 746	.0788	⅝	.46		106.6	83 70	26 16
⅞	.0729	35.37	2 579	2.025	.0985	¾	.47		111.4	87.46	27 94
15/16	.0781	37.89	2 960	2 325	.1211	⅞	.48		116.3	91 31	29 80
1	.0833	40.42	3 368	2.645	.1470	6	.50		121 3	95 23	31 74
1/16	.0885	42.94	3.803	2.986	.1763	¼	.52		131.6	103.3	35.88
⅛	.0938	45 47	4.263	3.348	.2093	½	.54		142 3	111.8	40 36
3/16	.0990	48 00	4 750	3.730	.2461	¾	.56		153 5	120 6	45 19
¼	.1042	50.52	5 263	4.133	.2870	7	.58		165.0	129 6	50.40
5/16	.1094	53 05	5 802	4.557	.3323	¼	.60		177.0	139 0	56 00
⅜	.1146	55.57	6 368	5.001	.3820	½	.62		189 5	148 8	62 00
7/16	.1198	58.10	6.960	5.466	.4365	¾	.64		202.3	158.9	68.40
½	.1250	60 63	7.578	5.952	.4960	8	.66		215.6	169.3	75.24
9/16	.1302	63.15	8 223	6.458	.5606	¼	.68		229.3	180.1	82.52
⅝	.1354	65 68	8.893	6 985	.6306	½	.70		243.4	191 1	90.25
11/16	.1406	68.20	9.591	7.533	.7062	¾	.72		257 9	202.5	98.45
¾	.1458	70.73	10 31	8 101	.7876	9	.75		272.8	214.3	107 1
13/16	.1510	73 26	11 07	8 690	.8750	¼	.77		288 2	226.3	116.3
⅞	.1563	75.78	11 84	9 300	.9688	½	.79		304 0	238 7	126.0
15/16	.1615	78 31	12 64	9 930	1 069	¾	.81		320 2	251.5	136.2
2	.1667	80 83	13 47	10 58	1.176	10	.83		336 8	264 6	146.9
¼	.1771	85.89	15.21	11 95	1.410	¼	.85		353 9	277 9	158.2
½	.1875	90 94	17.05	13 39	1 674	½	.87		371.3	291 6	170.1
¾	.1979	95.99	19.00	14 92	1.969	¾	.89		389 2	305.7	182 6
2½	.2083	101 0	21 05	16 53	2.296	11	.91		407 5	320 1	195.6
⅝	.2188	106 1	23 21	18 23	2 658	¼	.93		426 3	334 8	209 2
¾	.2292	111.2	25 47	20 01	3 056	½	.95		445.4	349.8	223 5
⅞	.2396	116.2	27 84	21.87	3 492	¾	.97		465 0	365 2	238 4
3	.2500	121.3	30 31	23 81	3 968	12	1.0		485 0	380 9	253.9

Wrought iron is here taken at 485 lbs. per cu. ft. Very pure soft wrought iron weighs from 488 to 492 lbs. per cu. ft. Light weight indicates impurities and weakness. Steel weighs about 490 lbs. per cu ft.; therefore FOR STEEL AN ADDITION MUST BE MADE TO THE TABULAR AMOUNTS OF ABOUT 1 LB. IN 100 LBS.

At 485 lbs. per cu. ft. a cubic inch weighs .28067 lb.; a lb. contains 3.5629 cu. in., and a ton, 4.6186 cu. ft.; and this is about the average of *hammered* iron. The usual assumption is 480 lbs. per cu. ft., which is nearer the average of ordinary *rolled* iron. At 480 lbs a cubic inch weighs .2778 of a lb.; a lb. contains 3.6 cu. in ; a ton 4.6667 cu. ft.; a rod of 1 sq. in. area weighs 10 lbs. per yard, or 3⅓ lbs. per foot, exactly.

Steel.

Steel has a chemical composition intermediate between cast iron and wrought iron. It is produced either by adding carbon to wrought iron, or by partly removing carbon from pig iron.

Steel is generally distinguished from both cast and wrought iron by the property of tempering which it possesses; that is to say, it can be hardened by sudden cooling from a high temperature, and its degree of hardness or softness can be regulated with precision by suitably fixing the temperature. But with the soft steels now produced this property is no longer a distinguishing sign, as many of them will not take a temper.

Steel may be distinguished from wrought iron by placing a drop of nitric acid upon it. If a dark-gray stain is produced it is steel.

Varieties of Steel.

Steel is made by many processes, of which the following are the most important:

Blister Steel is made by a process called *cementation*, in which bars of the purest wrought iron are embedded in layers of charcoal, and subjected for several days to a high temperature. Each bar absorbs carbon, and its surface becomes converted into steel, while the interior is in a condition intermediate between steel and iron. The steel receives its name from blisters which appear upon the surface: when these are small in size and are regularly distributed, the steel is of good quality; when they are large and irregularly distributed, it indicates a want of homogeneity in the iron used.

Blister steel cannot be used for ordinary forging, nor for cutting tools. It is used for facing hammers and for making other varieties of steel.

Shear Steel is made by breaking bars of blister steel into short lengths, making them into bundles, sprinkling with borax and sand, and heating them to a welding heat, then rolling or hammering them until a near approach to uniformity of composition and texture has been obtained. The product is termed *single-shear* steel, and if repeated the product is termed *double-shear* steel. It is used for various tools and cutting implements.

Puddled Steel is produced by stopping the puddling process in the manufacture of wrought iron before all the carbon has been removed. It is of inferior quality, used for making plates for ship-building.

A similar product resulting from imperfect refining is known as *Natural Steel* or *German Steel.*

BESSEMER PROCESS.—In this process pig iron of a dark-gray color, containing a large proportion of carbon, with but a small percentage of silicon and manganese and practically no sulphur and phosphorus, is melted in a cupola, or run direct from the blast-furnace into a "converter," which is a pear-shaped vessel lined with fire-brick, while in the converter a strong blast of air is forced through the molten metal for about twenty minutes. The color of the flame indicates to the experienced eye when all the carbon is removed, or more accurately determined by means of a spectroscope. Then from 5 to 10 per cent of *spiegeleisen* is added. The molten metal is again agitated by the air-blast, and when the two metals are thoroughly incorporated the steel is run into ladles and thence into the moulds. The ingots thus obtained are not as compact as required, but are made so by hammering. They are then rolled into the desired sizes and shapes for use.

THE BASIC PROCESS is similar to the preceding. The converters are lined with magnesian limestone or some refractory substance which contains practically no silica. In this process the silicon, carbon, and phosphorus are removed.

SIEMENS OR OPEN-HEARTH PROCESS.—In this process pig iron and ore are fused on the open hearth of a regenerative gas furnace. The pig iron is first melted and raised to a temperature which will melt steel; rich and pure ore and limestone are added gradually. The chemical reactions convert the silicon into silicic acid, which forms a fusible slag with the lime, and the carbon passes off as carbonic acid. A modification of this process consists in treating the iron ore in a rotary furnace with carbonaceous matter, by which both sulphur and phosphorus are removed.

SIEMENS-MARTIN PROCESS.—In this process a bath of highly heated pig iron is prepared in a furnace, and three or four times its weight of scrap-iron and steel are added and dissolved in the bath with enough ore to reduce the carbon to about 0.1 per cent. The furnace then contains a fluid malleable iron, to which is added silicious iron, *spiegeleisen,* or *ferro-manganese* in such proportions as are necessary to produce a steel of the requisite hardness.

The open-hearth processes require from 7 to 10 hours for one heat, while the Bessemer blow can be made in about half an hour.

The terms *acid* and *basic* process refer to the character of the lining of the converter or hearth of the furnace—*acid* signifying

that a silicious material, as sandstone or quartz, is used for the lining, and *basic* that lime and magnesia as existing in calcined dolomite are used. There are diverse opinions as to the relative values of steel made by the acid and basic processes. In the acid open-hearth process the stock used is usually very low in phosphorus at the start.

The terms "Bessemer" and "open-hearth" steels have reference to methods and processes, and not to qualities.

CAST STEEL is produced by various processes, either by melting fragments of steel produced by any of the other processes, or by melting wrought iron made from the purer magnetic ores with carbon, spiegeleisen, oxide of manganese, etc.

Cast steel is strong and hard, can be forged but not welded (made by Heath's process it is capable of being welded to other portions of the same material or to wrought iron). If raised beyond a red heat it becomes brittle.

Blow-holes may be diminished if not entirely prevented by the addition of manganese and silicon in sufficient quantities, but both of these cause brittleness.

Classification of Steel.

For convenient distinguishing terms, it is customary to classify steel in three grades, viz., "mild or soft," "medium," and "hard"; and although the different grades blend into each other so that no line of distinction exists, in a general sense the grades below 0.15 per cent carbon are considered as "soft," from 0.15 to 0.30 per cent carbon as "medium," and above 0.30 per cent of carbon as "hard." Each grade has its own advantages for the particular purpose to which it is adapted.

The soft steel is well adapted for boiler-plate and similar purposes, where its high ductility is advantageous. The medium grades are used for general structural purposes, while the hard grades are especially adapted for axles and shafts, and any service where good wearing surfaces are desired. Plate steel is usually graded as follows:

TANK STEEL (the cheapest).—Hard and brittle; also steel plates rejected from the higher grades.

SHELL STEEL.—Soft steel, usually made by the open-hearth process, and used for boilers, stand-pipes, etc.

FLANGE STEEL.—A superior quality of soft steel.

ORDINARY FIRE-BOX STEEL and LOCOMOTIVE FIRE-BOX STEEL are high grades of soft steel possessing special properties which fit them for the use indicated by their trade designation.

Properties of Steel.

SPECIFIC GRAVITY.—Average 7.854. The specific gravity of steel is influenced not only by its chemical constituents, but by the heat to which it is subjected, and also according to the degree of condensation imparted by the process of rolling or forging. The average given above has been adopted as the result of a number of careful experiments.

WEIGHT PER CUBIC FOOT, 490 LBS.—This figure is taken for convenience. The weight is affected by the same causes stated under specific gravity, and varies from 489.6 to 489.77. A weight extensively used is 489.6 lbs. per cubic foot, or about 2 per cent more than wrought iron.

MELTING-POINT.—Soft steel, 2372° to 2542° F.; hard steel, 2570° F.; mild steel, 2687° F.

SPECIFIC HEAT, .1165.

CONDUCTIVITY OF HEAT, 11.6.

CONDUCTIVITY OF ELECTRICITY, 12 (silver being 100).

EXPANSION AND CONTRACTION.—Expansion per degree Fahr. per unit of length = 0000064, or $\frac{1}{8}$ inch in 1575 ft. For a variation in temperature of 100 degrees F. the change in length will be about one inch in 125 feet.

EXTENSION is about .1 inch in 111 feet for every ton per square inch of load.

STRENGTH OF STEEL.—The strength of steel depends largely on the amount of the constituent elements that are associated with the iron, and each of which affects more or less the hardness and strength of the metal.

The principal of these are carbon, manganese, silicon, phosphorus, and sulphur. The first named is purposely retained as useful or necessary; the others are rejected, as far as practicable, as objectionable when in excess of certain minute proportions.

The tensile strength ranges from 25,000 to 180,000 lbs. per square inch; it is increased by reheating and rolling up to the second operation, but decreases after that.

As a general rule, the percentage of carbon in steel determines its hardness and strength. The higher the carbon the harder the steel, the higher the tenacity, and the lower the ductility will be.

The following table exhibits the average physical properties of good open-hearth steel:

TABLE 14.

PHYSICAL PROPERTIES OF OPEN HEARTH BASIC STEEL.

Grade.	Percentage of Carbon.	Tensile Strength. Lbs. per Square Inch.		Ductility.	
		Ultimate Strength.	Elastic Limit.	Elongation in 8 Inches.	Reduction of Fractured Area.
				per cent.	per cent.
Soft........	.08	54,000	32,500	32	60
"	.09	54,800	33,000	31	58
"	.10	55,700	33,500	31	57
"	.11	56,500	34,000	30	56
"	.12	57,400	34,500	30	55
"	.13	58,200	35,000	29	54
"	14	59.100	35,500	29	53
Medium....	.15	60,000	36,000	28	52
"	.16	60,800	36,500	28	51
"	.17	61,600	37,000	27	50
"	.18	62,500	37,500	27	49
"	.19	63,300	38,000	26	48
"	.20	64,200	38,500	26	47
"	.21	65,000	39,000	25	46
"	.22	65,800	39,500	25	45
"	.23	66,600	40,000	24	44
"	.24	67,400	40,500	24	43
"	.25	68,200	41,000	23	42
"	.30	77,000	46,000	20	35
Hard.......	.35	82,000	49,000	18	30
"	.40	87,000	52,000	16	25

WORKING STRENGTH in tension members is usually taken at 16,000 lbs. per square inch for angles and channels, and at 18,000 lbs. for round or flat bars. For columns the compression strain is taken at from 12,000 to 14,000 lbs. per square inch of section when the length is less than 90 radii.

TENACITY AT HIGH TEMPERATURES.—The strength of steel diminishes as the temperature increases from 0° until a minimum is reached between 200° and 300° F., the total decrease being about 4000 lbs. per square inch in the softer steels, and from 6000 to 8000 lbs. in steels of over 80,000 lbs. tensile strength. From this minimum point the strength increases up to a temperature of 400° to

600° F., the maximum being reached earlier in the harder steels, the increase amounting to from 10,000 to 20,000 lbs. per square inch above the minimum strength at from 200° to 300°. From this maximum the strength of all steel decreases steadily at a rate approximating 10,000 lbs. decrease per 100° increase of temperature. A strength of 20,000 lbs. per square inch is still shown by steel containing 0.10 carbon at about 1000° F., and by steel containing 0.60 to 1.00 carbon at about 1600° F.

STRENGTH OF WELDS.—

Strength of solid bar......	54.226 to 64.580 lbs. per square inch	
" " welded bar....	28.553 to 46.019 " " " "	

Mild steel has superior welding property as compared to hard steel, and will endure higher heat without injury.

HARDENING.—Steel containing about .40% carbon will usually harden sufficiently to cut soft iron and maintain an edge.

Steel Alloys.

MANGANESE, NICKEL, CHROME, AND TUNGSTEN STEELS are made by adding a small percentage of the metals named to the molten steel, the result in each case being a steel of great hardness and tenacity.

Manganese steel is very free from blow-holes; it welds with great difficulty; its toughness is increased by quenching from a yellow heat; its electric resistance is enormous, and very constant with changing temperature. It is low in thermal conductivity. Its great hardness cannot be materially lessened by annealing. At a yellow heat it may be forged readily, but at a bright red heat it crumbles under the hammer. But it offers great resistance to deformation, i.e., it is harder when hot than carbon steel.

Nickel steel possesses great tensile strength and ductility, high elastic limit and homogeneity, great resistance to cracking, a property to which the name *non-fissibility* has been given. It forges readily, whether it contains much or little nickel. If the proportion of nickel rises above 5%, cold working becomes difficult.

The tensile strength of forged bars containing 3¼% nickel ranges from 105,300 to 276,800 lbs. per sq. in.; of rolled bars, from 86,000 to 143,000 lbs. per sq. in. The strength of rolled bars containing 27% nickel ranges from 102,000 to 118,000 lbs. per sq. in. With 27% of nickel the steel is practically non-corrodible and non-magnetic.

Chrome and Tungsten Steel are made by adding a small percentage of chromium or tungsten to steel, the result producing a steel of great hardness and tenacity.

Alloys of steel with silver, platinum, aluminum, etc., are made with the view of improving the fabrication of the finer grades of surgical and other instruments.

Compressed Steel.—In the Whitworth process steel is subjected to compression while fluid under a pressure of from 4 to 12 tons per square inch. The pressure is applied and increased gradually Within half an hour or less after the application of the pressure the column of fluid steel is shortened 1½ inches per foot, or about one eighth of its length; the pressure is kept on for several hours, the result being that the metal is compressed into a perfectly solid and homogeneous mass, free from blowholes.

Terms used in Steel-working.

Bled Ingots.—Ingots from the centre of which molten steel has escaped, leaving a cavity.

Burned Steel.—Steel that has been partly reduced to oxide by overheating.

Check.—A small rupture caused by water. It may run in any direction. It is usually invisible until the steel is ruptured.

Chemical Numeration.—The chemical quantities of carbon, etc., are expressed in hundredths of one per cent. In the mill the steel is spoken of as 20 or 50 carbon, or 8 phosphorus, or 10, 15, or 25 silicon, etc., meaning that the steel contains twenty hundredths of one per cent of carbon, etc.

Dead melting (synonym, killing) means melting steel in the crucible or open hearth until it ceases to boil or evolve gases. It is then dead,—it lies quiet in the furnace,—and, killed properly, it will set in the moulds without rising or boiling.

Grade applies to quality—as crucible, Bessemer, or open-hearth grade; or, in the crucible, common spring, tool, special tool, machinery, etc., etc. It does not indicate temper or relative hardness.

Overblown.—Steel that has been blown in a Bessemer converter after the carbon is all burned; then there is nothing but steel to burn, and the result is bad.

Overheated.—Steel that has been heated too hot; its fiery fracture exposes it. The grain of overheated steel may be re-

stored, but restored steel is never as reliable as steel that has not been overheated. Overheating is a disintegrating operation.

OVERMELTED.—Steel that has been kept too long in fusion. The finest material may be ruined by being kept in the furnace any considerable time after it has been killed.

POINT.—One hundredth of one per cent of any element, as 10 points of carbon, or 10 carbon, etc.

RECALESCENCE.—The name given to the phenomenon which occurs when a piece of steel is heated above medium orange and allowed to cool slowly.

RESTORING.—The operation of reheating overheated steel and allowing it to cool slowly, by which operation its grain becomes fine and its fiery lustre disappears.

SHORT (*Cold, Red, Hot*).—*Cold-short* steel is weak and brittle when cold.

Red-short steel is brittle at dark-orange or medium-orange heat or at the common cherry-red. It may forge well at a lemon heat, and be reasonably tough when cold.

Hot-short steel is brittle and friable above a medium-orange color. It may forge well from medium orange down to black heat.

TEMPER.—Used by the steel-maker, it means the quantity of carbon present. It is low temper, medium, or high, or number so and so by his shop numbers.

Used by the steel user or the temperer, it means the color to which hardened steel is drawn—straw, brown, pigeon-wing, blue, etc., etc.

Or, it is the steel-maker's measure of initial hardness, and it is the steel-user's measure of final hardness.

WATER-CRACK.—A crack caused in hardening; it may run in any direction governed by lines of stress in the mass. It is distinguished from a *check* by being larger, and usually plainly visible.

WILD STEEL.—Steel in fusion that boils violently, and acts in the moulds as lively soda-water or beer does when poured into a glass.

Mill Inspection of Steel.

Steel Ingots are examined to discover the following defects:

BLOW-HOLES or cavities caused by the escape of gas evolved during cooling and solidification. These under some conditions of melting and composition occur throughout the mass, but especially near the surface and toward the upper part of the ingot.

PIPE.—A cavity caused by the outside of the ingot cooling more rapidly than the inside. This defect usually concentrates within conical lines in about the upper third of the ingot, but may occur anywhere by bad teeming.

EXTERNAL CRACKS caused by the rapid shrinkage of the outside or skin of the ingot, and at times due to hydrostatic pressure of the internal and fluid portion.

INTERNAL CRACKS due to interior strains set up by too rapid cooling, and occurring most frequently in ingots of hard steel.

SEGREGATION.—The separating and gathering together by themselves during cooling of certain chemical constituents—notably phosphorus, sulphur, and carbon, and to a less degree silicon and manganese. The segregation is generally toward the central and upper portion of the ingot, where cooling and solidification of the metal last takes place. The selection of the most highly segregated spots for analysis will give a knowledge of the worst possible condition of the metal. In order to avoid extreme segregation no ingot should be cast of a greater weight than 15,000 pounds.

Ingots should be bottom cast, and should not be disturbed or moved from the position in which they are cast until sufficiently solidified to preclude "bleeding." Bled ingots and ingots not bottom cast should be rejected.

The inspector of ingots should note especially casts that have been too violently or quickly melted or burnt, and report the same, so that steel rolled therefrom may be subjected to special examination.

APPEARANCE OF GOOD STEEL.—The appearance of the fresh fracture of an ingot will give an indication of the quality of the steel. If the color be a bluish gray, with uniform grain, slight lustre, and silky appearance, it is an indication of good steel, and the steel-worker will say that it is "sappy"—meaning that it is just right. If the fracture be dull and sandy looking, without lustre or sheen, and without the bluish cast or having more of a shade of yellowish sandstone, it is an indication of impurity and

weakness, and the steel-worker will say it is "dry." If the fracture be granular, with bright flashing lustre, the steel-worker will say it is "fiery." This condition is an evidence of high heat. If the grain be fairly fine and of a bluish cast, it is not necessarily bad. In mild steel, in high steel, or in tool steel it should not be tolerated. If the grain be large and of a brassy cast, it is an evidence of bad condition. The grain should be restored before the steel is used. In hardened steel it is always bad, except in dies to be used under the impact of the drop-hammer; in this case steel must be so hard as to be slightly fiery.

The quality of the steel from each heat or blow is ascertained by testing specimens obtained by casting small billets about 4 in. square and rolling them down into a ¾-in. round.

These tests will usually run a little below the final finished material tests in elastic limit and ultimate strength, and a little above them in elongation and reduction. Allowance should be made for this variation in the acceptance of the heat.

The amount of phosphorus, etc., is determined from the same billets before the ingots are rolled, or from drillings taken directly from one of the ingots.

The samples for chemical analysis should be sent to the laboratory without unnecessary delay.

MARKING INGOTS.—Each ingot should be marked plainly with its melt number, and this melt number must be stamped or painted on all blooms, billets, or slabs made from such ingots, in order to identify the material through its various processes of manufacture, and the melt number, together with the furnace-heat number, must be plainly marked on each piece of finished material.

MELT RECORDS.—A complete record of each melt should be kept, showing character of the raw materials, the number, size, and weight of each ingot cast, the number of ingots rejected, and the reasons therefor.

Rolled Steel.—When the rolling is made the inspector should be on hand to see that the bars are of the required size and free from defects; at the same time he should select the test-pieces.

The defects causing rejection of rolled steel are as follows:

BLOW-HOLES and PIPES caused by the non-removal of these defects from the ingot.

STARS.—Brilliant spots in mid-section showing that the pipe was not all cut away from the ingot.

PITS.—Caused by burning; they occur in the form of small cup-like holes, and must not be confounded with cinder spots.

CINDER SPOTS are due to pieces of cinder or fire-brick being rolled into the metal.

CRACKS.—Due to rolled-out blow-holes. If a bar, plate, or beam shows cracks on the surface or at the corners, with rough, torn surfaces, the steel has either been superficially burned or it is *red-short*. In either case it should be rejected, for the cracks, although they may be small, will provide starting-points for ultimate fractures.

LAPS OR LAMINATIONS.—A lap or lamination is caused by careless hammering, or by badly proportioned grooves in rolls, or by careless rolling. A portion of the steel is folded over itself, the walls are oxidized and cannot unite. A lap generally runs clear along a bar practically parallel with its axis; it is easily seen.

SEAMS.—A seam is a longer or shorter defect caused by a blow-hole which working has brought to the surface and not eliminated. It usually runs in the direction of working. Seams are distinguished from laps by not being continuous; they are usually only an inch or two in length.

SNAKES are small lines twisting in every direction due to foreign substances in the heat separating two masses of pure steel.

COBBLES are irregularities due to one side being heated more than another.

APPEARANCE OF FRACTURED SURFACE.—The appearance of the fractured surface of steel is by many persons considered an index to the quality. With great experience on the part of the observer it may serve as a guide, but as a rule it is vague and uncertain.

The appearance of the fracture is influenced by the manner in which the metal is broken. When rupture takes place *slowly* the fracture presents a silky fibrous appearance with an angular and irregular outline. When ruptured *suddenly* the fracture presents a granular appearance with the surface usually even and at right angles to the length.

The color is a light pearl-gray, slightly varying in shade with the quality; the granular fractures are usually almost free from lustre, and, consequently, totally unlike the brilliant crystalline appearance of wrought iron.

The last highest temperature to which steel was subjected can be very closely judged by the appearance of a cold fracture.

If the heating and working were uniform the fracture will show an even grain throughout.

A proper heat is indicated by a fine lustreless grain with a steely blue or gray color.

Too high heat is indicated by a coarse lustrousless grain with a yellowish cast.

Too low a temperature is shown by a fine grain of a black or decided blackish color.

Uneven heating or working, or both, is shown by an uneven grain.

If the outside be fine-grained and the centre part be coarse and fiery it shows high initial heat modified by superficial and insufficient working, either under the hammer or in the rolls.

If the inside be fine-grained and the outside be coarse and fiery it shows that the last heat was too high, too quick and superficial.

If the corners be coarse and fiery and the body of the piece be of proper grain it shows carelessness in heating, allowing the corners of the piece to run up much hotter than the body.

The fracture of burned steel has a whitish hue, the crystals show bright and fiery, and show distinct, well-defined faces, whether large or small, and the granular or crystalline appearance of the fracture is very marked and coarse.

The nicked bending fracture of soft steel not burned will have a bluish-gray hue, with the structure not sharply defined or even "mushy" in appearance.

Steel for Boilers.—In selecting steel for boilers, especially for locomotive boilers, the inspector should look for a peculiar marking which will appear on the test-pieces if the metal has the desired quality. This marking consists of a series of faint lines running criss-cross and intersecting at the same angle. Some call it the skeleton of the steel. When this marking is found in an open-hearth steel specimen, and the other results of the test are satisfactory, the inspector may rest assured that the metal is of suitable quality for boilers. Why steel with this marking should give good results no one knows, but many years of experience and investigation have shown it to be the case. If the steel is entirely uniform and the test-piece shows no marking of any kind it is unsuited for boilers. It will crack and break, and become "mushy" or honeycombed. Good boiler steel should not show a sudden reduction at the fracture, there should be a gradual reduction, and the occurrence of even a slight shoulder

on the contracted part should cause the steel to be looked on with suspicion.

Steel Castings..—The defects to be looked for in steel castings are blow-holes, shrinkage-cavities, pits, and cracks.

Appearance of Fracture.—The fracture of cast steel should have a slaty-gray tint, almost without lustre, the crystals being so fine that they are hardly distinguishable.

The behavior of an unannealed steel casting resembles that of an overheated forging; its chief characteristic is its brittleness when subjected to shock. Hard castings have this property to such a marked degree that sinking-heads are often broken off by the shock of chipping off the runner.

The strains caused by shrinkage in cooling are frequently so great as to cause rupture.

Shrinkage of Steel Castings.—In steel castings the amount of shrinkage varies with the composition and the heat of the metal; the hotter the metal the greater the shrinkage.

The allowance for shrinkage is from $\frac{3}{16}$ to $\frac{1}{4}$ inch per foot in length, except in very heavy castings, where $\frac{1}{8}$ inch is sufficient, and $\frac{1}{4}$ inch for finish on all machined surfaces, except such as are cast "up." Cope surfaces which are to be machined should, in large or hard castings, have an allowance of from $\frac{3}{8}$ to $\frac{1}{2}$ inch for finish, as a large mass of metal slowly rising in a mould is apt to become crusty on the surface, and such a crust is sure to be full of imperfections. On small, soft castings $\frac{1}{8}$ inch on drag side and $\frac{1}{4}$ inch on cope side will be sufficient. No core should have less than $\frac{1}{4}$-inch finish on a side, and very large ones should have as much as $\frac{1}{2}$-inch on a side.

Specifications for Steel Castings (U. S. Navy Department).—Steel for castings must be made by either the open-hearth or crucible process, and must not show more than 0.06 of phosphorus. All castings must be annealed unless otherwise directed.

The tensile strength of steel castings shall be at least 60,000 lbs., with an elongation of at least 15 per cent in 8 inches for all castings for moving parts of machinery and at least 10 per cent in 8 inches for other castings. Bars 1 inch square shall be capable of bending cold, without fracture, through an angle of 90° over a radius not greater than $1\frac{1}{8}$ inches. All castings must be sound, free from injurious roughness, sponginess, pitting, shrinkage, or other cracks, cavities, etc.

The test-strip should be poured along with the casting; its dimensions should be $\frac{3}{4}$ inch square by 12 inches long.

Checking and Marking Accepted Material.—In the mill inspection of iron and steel the inspector should have a copy of the mill order and check off such as he accepts, so that he as well as the mill people may know how much remains to be done.

Every accepted piece of material should be marked with a distinguishing mark. (The best form of marking-tool is a small steel hammer with a mark cut on one end) The imprint on the metal should be surrounded by a ring of white paint so as to be readily seen. To the shopmen this stamp should be the signal that they can proceed with the required shop manipulations without asking questions.

Tests for Steel.

The tests to which steel is subjected are much more rigid than for wrought iron destined for similar purposes. The reasons for this are that the acceptable qualities of one melt of steel offer no absolute guarantee that the next following melt from the same stock will be equally satisfactory. Moreover, steel is much more affected in the various processes of hardening, cold-rolling, overheating, etc., than iron. While soft steel of good quality is for many purposes a safe and satisfactory substitute for wrought iron, a poor steel or an unsuitable grade of steel is a dangerous substitute, for it may range from the brittleness of glass to a ductility greater than that of wrought iron.

The tests usually prescribed by specifications to determine the quality of steel are :

TENSILE TESTS, including the elastic limit and ultimate strength as measures of tenacity, together with the percentage of elongation and reduction of area as measures of ductility ; also bending, drifting, and forging tests, and chemical analysis to determine percentage of phosphorus, etc.

The number of tests to be made will depend upon circumstances and the specific instructions given by the engineer. Common requirements are that a test-bar must be rolled from every melt, and that three tests of each kind shall be made from different ingots of each melt.

BENDING TEST (*Hot*). — Test-pieces of medium steel when heated to a cherry-red and cooled in water at 70° F. shall bend 180 degrees round a circle whose diameter is equal to the thickness of the test-piece, without showing signs of cracking on the convex side of the curve.

Bending Test (*Cold*).—Specimens of rivet or soft steel shall bend cold through 180 degrees, and close down flat upon themselves without cracking.

If material of various shapes is to be made from the same melt the specimens for testing are to be so selected as to represent the different shapes rolled.

Bending tests are usually made on flat strips one inch wide and of the finished thickness of the metal, on round rods as they come from the rolls.

Drifting Test.—Made by striking with a sledge upon a steel drift-pin in punched holes and noting the size to which these holes can be enlarged under different circumstances without fracture of the material.

A hole punched for a $\frac{3}{4}$-inch rivet, its centre being $1\frac{1}{8}$ inches from the rolled or planed edge, is required to be capable of enlargement in this way without fracture of the metal until it will pass a rod of the diameter of 1 inch for wrought iron, $1\frac{1}{4}$ inches for bridge steel, and $1\frac{1}{2}$ inches for boiler-plate steel.

The test-piece should be supported on the under side by a surface having a hole with a rounded edge, slightly larger than the punched hole to start with, and the size of holes increased as the drift-pin is driven through. Blank nuts make a very good support.

The drift-pin in starting should be entered from the lower side of the punched hole on account of the taper in the hole and in order that the fin left in punching may be drawn in by the drift-pin.

The results of this test are affected by the weight of the sledge, the number of blows, the height of fall and rapidity of the blows, all of which should be noted and recorded.

Hardening Tests.—These are made by heating a test-piece to a red heat and plunging into water at 32° to 40° F.; the piece is then bent and the results compared with those on a similar piece not hardened.

Forging Test.—This test is chiefly used for rivet-rods. A part of the rod is brought to a fair red heat and hammered until cracks barely begin to show at the edge of the piece. The amount of flattening which the piece stands before cracks appear shows the red-shortness of the material.

Welding Test.—A piece of metal with section about 1 inch in largest dimension is to be prepared for a single scarf-weld and heated in a reducing flame in a clean fire. At a white heat it is

to be removed and welded with an 8- to 10-lb. hammer, then upset while still hot, and finally drawn down under the hammer to its original size. No flux and no water are to be used. One bar welded in this way is to be tested in tension; another is to be nicked to the depth of the weld and bent or broken if possible to show the character of the welded surfaces.

HOMOGENEITY TEST.—A portion of the test-piece is nicked with a chisel, or grooved on a machine, transversely about $\frac{1}{16}$ inch deep, in three places about 1½ inches apart. The first groove should be made on one side 1½ inches from the square end of the piece; the second, 1½ inches from it on the opposite side; and the third, 1½ inches from the last, and on the opposite side from it. The test-piece is then put in a vise, with the first groove about 1¼ inches above the jaw, care being taken to hold it firmly. The projecting end of the test-piece is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The piece is broken at the other two grooves in the same manner. The object of this treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or to cavities due to gas-bubbles in the ingot.

After rupture one side of each fracture is examined, a pocket-lens being used, and the length of the seams and cavities is determined. The length of the longest seam or cavity determines the acceptance or rejection of the plate. (Any seam or cavity ¼ inch long in either of the three fractures should cause rejection.)

QUENCHING TEST.—Steel heated to cherry-red, plunged in water at 82° Fahr., then bent round a curve 1½ times the diameter of the plate, should show no signs of fracture on the outside of the curve.

Steel below .10 carbon should be capable of doubling flat without fracture after being chilled from a red heat in cold water. Steel of .15 carbon will occasionally admit of the same treatment, but will usually bend around a curve whose radius is equal to the thickness of the specimen; about 9 per cent of specimens stand the latter bending test without fracture. As the steel becomes harder its ability to endure this bending test becomes more exceptional, and when the carbon ratio becomes .20 little over 25 per cent of specimens will stand the last-described bending test.

ACID TESTS FOR IRON AND STEEL.—The sample to be tested is filed smooth on all sides, then placed in dilute nitric or sulphuric

acid from 12 to 24 hours, then washed and dried. The action of the acid has revealed the structure of the material, from which its quality can be decided with great precision.

The best steel presents a frosty appearance, ordinary steel honeycombed; the best iron shows the finest fibres. Should the iron be uneven or made from a pile of different kinds of iron all are exposed by the action of the acid. Hammered blooms show slag and iron. Gray cast iron shows crystals of graphitic carbon; other cast iron shows different figures, all with marked characteristics.

Shop Inspection of Iron and Steel.

The various processes in the shop are the same for both iron and steel, and are as follows: (1) Straightening (when necessary), (2) marking off and punching, (3) straightening, (4) reaming, (5) assembling, (6) reaming, (7) riveting, (8) facing, (9) boring, (10) finishing, (11) fitting up, (12) oiling and painting, (13) shipping.

After the material has reached the shop the inspector wants to watch the work as it proceeds through the various stages to see that the workmanship is good and that the material is not maltreated. He should have in his possession a copy of the specifications, a bill of the material, and a set of working drawings.

He should make a critical examination of all the dimensions of finished parts, location of rivet- and bolt-holes for field connection, and have all errors corrected.

STRAIGHTENING.—The inspector should see that any of the material which may have been bent in transferring from the mill to the shop is properly straightened before being laid off for punching. After punching the material must be again straightened, because it is more or less buckled during the process. If not straightened the several pieces to be riveted together cannot be made to fit properly, and when riveted there will be sufficient spring between the pieces to distort the rivet, and many of them will be found to be loose on cooling. The finished member also never looks as well as if the material had been straightened.

RIVETING.—The punch-dies should be examined occasionally to see that the edges are sharp and unbroken, and that the difference in diameter between the upper and lower does not exceed $\frac{1}{16}$ inch.

If the rivet-holes are worked with templets the templets must lie flat without distortion when the marking is done.

Where riveting is to be done in the field the parts must be fitted together in the shop and the rivet-holes reamed out while they are assembled, or an iron templet should be made and both parts reamed to fit it.

Web-splices and all abutting sections should be made to close tightly and the splice-plates fitted on and reamed while in position.

DRIFTING for any purpose other than bringing the piece to the proper position should not be allowed. After the work is bolted together and some rivets driven the use of the drift-pin is dangerous, as it is now enlarging the rivet-hole at the expense of serious compression in some of the component pieces; there can be nothing but distortion, as the work is held by the rivets already driven.

The inspector should see that a sufficient number of bolts are used to hold the pieces snugly together while being riveted; also that all stiffeners fit tightly and that all surfaces to be riveted together are painted before being bolted up.

As soon as the riveting is done each rivet should be examined to see that it is properly formed and tightly driven. (See Riveting, page 194.)

FACING AND BORING.—In facing and boring care should be taken that the ends of each piece are planed to the proper length and bevel, and that pin-holes are of the proper size and distance apart from centre to centre.

The inspector should supervise the laying out of the sections that are to be fitted together in the field, and see that everything goes together, so that no unnecessary work will have to be done in the field.

After the shop-work is completed, and before painting or oiling is commenced, the inspector should satisfy himself that everything has been done according to the specifications and drawings; any part found unsatisfactory should be replaced and perfected. The parts found satisfactory should be marked.

COMPARING MEASURES.—The steel tape and other measures used by the inspector should be compared with the standard used in the shop, and corrected if necessary.

Records.—A daily record of the progress of the shop-work must be kept, and especially if there is a time-penalty clause in the specifications. A record-book ruled as below will be found useful:

[*Left-hand page.*]

No. of Drawing.	Name of Piece.	Date.	Punched.	Reamed.	Riveted.

[*Right-hand page.*]

Bolted.	Bored.	Milled.	Turned.	Remarks.

To avoid the frequent handling of a large number of sheets of drawings, tables containing all of the important descriptions of the several pieces should be prepared in note-book form somewhat on the following plan:

CHORDS AND POSTS.

No. of Drawing.	Name of Piece.	Length Over All.	Length between Pin Centres.	Size of Pin-hole.	Size of Web or Bar.	Size of Chord-angles.	Thickness of Pin-bearing.	Clearance.	Cover-plates.	Splice-plates.	Remarks.

For floor-beams and stringers the table would be as follows :

FLOOR-BEAMS AND STRINGERS.

No. of Drawing.	Name of Piece.	Length.	Size of Chord-angles.	Size of End-stiffeners.	No. of Rivets in End-connections.	Size of Web.	Remarks.	Bevels.			
								Vertical.		Horizontal.	
								Fixed End.	Expansion End.	Fixed End.	Expansion End.

Tables for other items, as pins, rollers, eye-bars, bracing-rods, lateral plates, pedestals, etc., are easily formed.

The keeping of a complete record of the work involves considerable clerical work, which has to be done at odd times and in the evening. But the time and labor expended are paid for many times over by the sense of absolute security which the inspector is thereby enabled to enjoy.

Where possible the inspector should see that the material is properly loaded on the cars for shipment in order to prevent its being bent or twisted in transit. He should also approve the itemized bill of lading of each car-load of material which he has accepted.

Notes on Working Iron and Steel.

Cold-rolling of iron and steel increases the elastic limit and the ultimate strength, but decreases the ductility.

PUNCHING AND SHEARING.—The physical effects of punching and shearing, as denoted by tensile tests, are for iron or steel: Reduction of ductility; elevation of tensile strength at elastic limit; reduction of ultimate tensile strength.

In very thin material the disturbance described is less than in thick. In material having a thickness of half an inch and upwards the loss of tenacity ranges from 10 to 23 per cent in iron plates and from 11 to 33 per cent in mild steel.

The effects described do not invariably ensue. For unknown reasons there are sometimes marked deviations from what seems to be a general result.

Annealing.—The object of annealing structural steel is for the purpose of securing homogeneity of structure that is supposed to be injured by unequal heating or by the manipulation attendant on certain processes. The objects to be annealed should be heated throughout to a uniform temperature and uniformly cooled.

The temperatures employed vary from 1000° to 1500° F. and possibly higher. In some cases the heated steel is withdrawn at full temperature from the furnace and allowed to cool in the atmosphere; in others the heated metal is removed from the furnace, but covered under a muffle to lessen the free radiation; or, again, the charge is retained in the furnace, and the whole mass cooled with the furnace, and more slowly than by either of the other methods.

Soft steel no matter how low in carbon will harden to a certain extent upon being heated red-hot and plunged into water; it will harden more when plunged into brine and less when quenched in oil.

Unannealed soft steel for a strength of 56,000 to 64,000 lbs. may be worked in the same way as wrought iron. Rough treatment or working at a blue heat must, however, be prohibited. *Shearing* is to be avoided except to prepare rough plates, which should afterwards be smoothed by machine tools or files before using. *Drifting* is to be avoided because the edges of holes are thereby strained beyond the yield-point. *Upsetting, cranking,*

and *bending* ought to be avoided, but when necessary the material should be annealed after completion.

Forging consists in raising metal to a high temperature and hammering it into any form that may be required.

In the operation of forging care must be exercised to avoid overheating or burning the metal. Steel requires more care than iron. Each variety of steel differs as to the heat to which it can safely be raised.

Shear steel will stand a white heat.

Blister steel will stand a moderate heat.

Cast steel will stand a bright red heat.

By overheating the tensile strength and ductility are both seriously injured.

After reaching the proper heat the metal should be worked as quickly as possible, as working at too low a temperature is also injurious.

Welding is the process by which two pieces of metal are joined together with the aid of heat.

Wrought iron possesses the property of welding to a high degree. At a white heat it is so pasty that if two pieces at this temperature be firmly pressed together and freed from oxide or other impurity they unite intimately and firmly.

Steel possesses the property of welding in an indifferent degree, which diminishes as the metal approximates to cast iron with respect to the proportion of carbon; or, what amounts to the same thing, it increases as the metal approximates to wrought iron with respect to the absence of carbon.

It is usually specified that *no welding* shall be allowed on any steel that enters into structures.

Hardening Steel.—If steel at a red heat be plunged into cold water it becomes hard. The more suddenly the heat is extracted the harder it will be.

The process of *hardening*, however, makes the steel very brittle, and in order to make it tough enough for most purposes it has to be *tempered.*

Tempering Steel.—The process of tempering depends upon the characteristic of steel, which is that if (after hardening) the steel be reheated, as the heat increases the hardness diminishes.

In order to produce steel of a certain degree of toughness it is gradually reheated, and then cooled when it arrives at that temperature which experience has shown will produce the limited degree of hardness required.

Heated steel becomes covered with a thin film of oxidation, which becomes thicker and changes color as the temperature rises. The color of this film is therefore an indication of the temperature of the steel upon which it appears.

Advantage is taken by the workman of this change of color. He watches for the arrival of the color due to the required temperature. When it appears he withdraws the tool from the fire and plunges it into cold water and moves it about until the heat has all been extracted by the water.

It is important that considerable motion should be given to the surface of the water while the tool is plunged in; otherwise there will be a straight line of demarcation between the hardened part and the remainder of the tool, and the metal will be liable to snap at this point.

Upsetting.—Enlarged ends on tension-bars for screw-threads, eye-bars, etc., are formed by upsetting the material. With proper treatment and a sufficient increment of enlarged sectional area over the body of the bar the result is entirely satisfactory.

The upsetting process should be performed so that the properly heated metal is compelled to flow without folding or bending.

Calking.—All calking-edges should be bevelled on a planer, and the calking should be done with a round-nosed tool. If a square-edged tool is used it creases the inner plate, and if this should prove to be of brittle steel it might cause a failure along this line.

Blue-shortness.—Steel and wrought iron are injured and rendered brittle by being worked at a blue heat, i. e., the heat that would produce an oxide coating ranging from light straw to blue on bright steel (430° to 600° F.).

A practice among boilermakers for guarding against failures due to working at a blue heat consists in the cessation of work as soon as a plate which had been red-hot becomes so cool that the mark produced by rubbing a hammer-handle or other piece of wood will not glow. A plate which is not hot enough to produce this effect, yet too hot to be touched by the hand, is most probably blue-hot, and should under no circumstances be hammered or bent.

Copper.

Copper is obtained from the ores by roasting, calcining, refining, and melting them with certain fluxes and oxidizing agents.

It is distinguished from all other metals by its reddish color.

It is very ductile and malleable and its tenacity is next to iron.

It cannot be welded. It may be worked either hot or cold.

It oxidizes very slowly in the air, becoming coated with a thin film of the carbonate called *verdigris;* this protects it from further oxidation.

It is corroded by salt water if at the same time air has access to it.

Copper is used for slate-nails, pipes, roofing-gutters, lightning-rods, and in the form of sheets, bars, and wire is extensively used in electrical work and for many other purposes.

Properties of Copper.

Specific gravity	8.81 to 8.95
Weight per cubic foot	Cast, 537 lbs. Sheet, 555 "
Melting-point	1930° F.
Atomic weight	63.2
Specific heat	.093
Conductivity of heat	73.6
" " electricity	99.95 (silver being 100)
Expansion between 32° and 212° F.	.0051

Resistance to tension, 20,000 to 33,000 lbs. per square inch, being reduced at a temperature of 400° F. 10 per cent, and at 500° F. 16 per cent.

Resistance to crushing .... 117,000 lbs. per square inch

Tests for Copper.—Copper in the form of plates, sheets, or bars is subjected to a tension test and to a bending test both hot and cold. Copper wire is subjected to tension, bending, and winding or torsional tests.

Table 15.

WEIGHT OF ROUND BOLT COPPER.

Diameter. Inches.	Weight per Foot. Pounds.	Diameter. Inches.	Weight per Foot. Pounds.
$\frac{3}{8}$	.425	$1\frac{1}{4}$	4.72
$\frac{1}{2}$	.756	$1\frac{3}{8}$	5.72
$\frac{5}{8}$	1.18	$1\frac{1}{2}$	6.81
$\frac{3}{4}$	1.70	$1\frac{5}{8}$	7.99
$\frac{7}{8}$	2.31	$1\frac{3}{4}$	9.27
1	3.02	$1\frac{7}{8}$	10.64
$1\frac{1}{8}$	3.83	2	12.10

TABLE 16.

COPPER AND BRASS. GAUGE AND WEIGHT OF WIRE AND SHEET.

No. of Gauge.	Size of Each No.	Weight of Wire per 1000 Lineal Feet.		Weight of Plates per Square Foot.	
		Copper.	Brass.	Copper.	Brass.
	Inch.	Pounds.	Pounds.	Pounds.	Pounds.
0000	.46000	640.5	605.28	20.84	19.69
000	.40964	508.0	479.91	18.55	17.53
00	.36480	402.0	380.77	16.52	15.61
0	.32476	319.5	301.82	14.72	13.90
1	.28930	253.3	239.45	13.10	12.38
2	.25763	200.9	189.82	11.67	11.03
3	.22942	159.3	150.52	10.39	9.82
4	.20431	126.4	119.48	9.25	8.74
5	.18194	100.2	94.67	8.24	7.79
6	.16202	79.46	75.08	7.34	6.93
7	.14428	63.01	59.55	6.54	6.18
8	.12849	49.98	47.22	5.82	5.50
9	.11443	39.64	37.44	5.18	4.90
10	.10189	31.43	29.69	4.62	4.36
11	.090742	24.92	23.55	4.11	3.88
12	.080808	19.77	18.68	3.66	3.46
13	.071961	15.65	14.81	3.26	3.08
14	.064084	12.44	11.75	2.90	2.74
15	.057068	9.86	9.32	2.59	2.44
16	.050820	7.82	7.59	2.30	2.18
17	.045257	6.20	5.86	2.05	1.94
18	.040303	4.92	4.65	1.83	1.72
19	.035890	3.90	3.68	1.63	1.54
20	.031961	3.09	2.92	1.45	1.37
21	.028462	2.45	2.317	1.29	1.22
22	.025347	1.94	1.838	1.15	1.08
23	.022571	1.54	1.457	1.02	.966
24	.020100	1.22	1.155	.911	.860
25	.017900	.699	.916	.811	.766
26	.014940	.769	.727	.722	.682
27	.014195	.610	.576	.643	.608
28	.012641	.484	.457	.573	.541
29	.011257	.383	.362	.510	.482
30	.010025	.304	.287	.454	.429
31	.008928	.241	.228	.404	.382
32	.007950	.191	.181	.360	.340
33	.007080	.152	.143	.321	.303
34	.006304	.120	.114	.286	.270
35	.005614	.096	.0915	.254	.240
36	.005000	.0757	.0715	.226	.214
37	.004453	.0600	.0567	.202	.191
38	.003965	.0476	.0450	.180	.170
39	.003531	.0375	.0357	.160	.151
40	.003144	.0299	.0283	.142	.135
Specific gravity............		8.880	8.386	8.698	8.218
Weight per cubic foot......		555.	524.16	543.6	513.6

Lead.

Lead is obtained by smelting the various lead ores, and as a by-product in the smelting of silver ores. It is soft, heavy, malleable, and ductile, but its tenacity is such that it can be drawn into wire with great difficulty. Is very fusible: melts at about 625° F., softens and becomes pasty at about 617° F. If broken by a sudden blow when just below the melting-point it is quite brittle and the fracture appears crystalline. It dissolves to some extent in pure water, but water containing carbonates or sulphates forms over it a film of insoluble salt which prevents further action. Lead is oxidized by rain-water, vegetable matter, lime, damp plaster, and wet wood; also by galvanic action when in contact with other metals in the presence of moisture. It is also rapidly destroyed by ammonia, acetates, nitrites, and nitrates in solution. It does not readily decompose on exposure to the atmosphere, being usually protected by the first coat of oxide which forms upon its surface.

The white lead of commerce is formed from the carbonate of lead. Red lead is a compound oxide of lead.

Properties of Lead.

Specific gravity	11.07 to 11.44
Weight per cubic foot	Cast, 709 lbs. Sheet, 713 "
Melting-point	625° F.
Atomic weight	206.4
Specific heat	.0314
Conductivity of heat	8.5
" " electricity (silver being 100)	8.3
Expansion between 32° and 212° F.	.0084
Resistance to tension	1600 to 2400 lbs. per sq. in.
Resistance to compression	7730 lbs. per sq. in.

Sheet Lead is either *cast* or *milled*, the former in sheets 16 to 18 feet in length and 6 feet in width; the latter is rolled, is thinner than the former, is more uniform in its thickness, and is made into sheets 25 to 35 feet in length, and from 6 to 7½ feet in width.

Sheet lead is usually described according to the weight of a superficial foot in pounds. The thicknesses corresponding to given weights are as follows:

TABLE 17.

THICKNESS AND WEIGHT OF SHEET LEAD.

Weight per Square Foot. Lbs.	Thickness. Inches.	Weight per Square Foot. Lbs.	Thickness. Inches.
1	0.017	8	0.135
2	0.034	9	0.152
3	0.051	10	0.169
4	0.068	11	0.186
5	0.085	12	0.203
6	0.101	14	0.237
7	0.118	16	0.271

Sheet lead is used in roofing for gutters, flashings, etc.; for lining cisterns, sinks, etc. The weights recommended for these purposes are as follows:

Roofs and gutters	7	lb. lead
Hips, ridges, and small gutters	6	" "
Flashings	4 and 5	" "
Cisterns and sink bottoms	7	" "
" " " sides	6	" "

Owing to the great expansion and contraction of lead from alterations of temperature it is not desirable to lay it in greater lengths than 10 or 12 feet without a joint roll or drip to allow for the changes in dimensions.

Lead Pipes are formed by *drawing, casting, pressing,* or *rolling* lead. They are usually described by the diameter and weight per foot, as shown in Table 65.

Tin.

Tin is obtained by roasting and smelting the ores—usually the binoxide and tin pyrites—in a reverberatory furnace, whence the liquid metal is run into a basin and thence into moulds. The ingots thus produced are refined and boiled.

Tin is a soft, malleable, fusible, white, lustrous metal of little strength. It resists oxidation better than any of the metals except gold and silver. Its chief uses are for coating sheet iron, called "tin plate," and for making alloys with copper and other metals.

Tin may be distinguished from other metals by the peculiar crackling sound (termed the "cry of tin") produced when bent. Its purity is tested by its extreme brittleness at high temperatures.

Tin in pigs or plate is subject to a peculiar form of disaggregation, especially when exposed to extreme cold and great changes of temperature. Thin sheet tin will sometimes, if exposed to the cold for long periods, be covered with blisters, become brittle, fall to pieces, and finally to powder. The cause of the decay of tin has not been definitely settled, but the presence of mercury seems to aid it.

Properties of Tin.

Specific gravity	7.293
Weight per cubic foot, cast	456 lbs.
Melting-point	442° F.
Atomic weight	118
Specific heat	.055
Conductivity of heat	14.5
" " electricity (silver being 100)	12.4
Expansion between 32° and 212° F	.0069
Resistance to tension	3500 lbs. per sq. in.
Resistance to compression	15,500 lbs. per sq. in.

Tin Plate is iron or steel plate covered with a coating of tin or an alloy of tin and lead.

Tin plate is extensively used for roofing, leader-pipes, flashing, and other purposes. Such plates are durable until a hole is made in the coating, when galvanic action sets up between the tin and iron; the tin is then rapidly eaten away.

Tin plate is made of sheet iron or steel coated with tin or a mixture of tin and lead. Plates of the first class are designated "bright tin" plate, and of the latter class "terne" (dull) plate. Very thin sheets which run below gauge (30 or lighter) are called "taggers" tin. Imperfect plates are called "wasters."

The plates are coated by various processes: 1. The *Dipping Process*, in which the plates, prepared by pickling in dilute sulphuric acid, annealing, and again pickling, are dipped in a bath of palm-oil, then in a bath of molten tin, from which they go to the rollers. "Redipped" plates are plates dipped a second time in the molten tin. *Acid Process:* In this process the cleaned and pickled plates are passed through a solution of muriatic acid and zinc chloride which floats on top of the molten tin. The zinc causes a quick galvanic action, and as the plates are immersed in the molten tin the tin by means of this galvanic action will adhere to the plates. The plates thus tinned are drawn through an oil bath. Plates prepared by this process are not as durable as those coated by the palm-oil process. *Roller Process:* In this process the plates are dipped in the molten metal, and then passed through rolls which work in a large vessel containing oil. The rolls are adjusted so as to leave a coating of greater or less thickness, which determines the value of the plate.

Two thicknesses of tin roofing-plates are made, namely, IC, or No. 29 gauge, weighing 8 oz. to the square foot, and IX, or No. 27 gauge, weighing 10 oz. to the square foot.

The sizes of plates generally used for roofing are 14 × 20 and 20 × 28 in. The larger size is more extensively used, because it requires less seams and consequently cheapens the cost of putting on; but a better roof is obtained by using 14″ × 20″, because the seams are closer together, thus making the roof stronger; and if put on with a standing seam there is more allowance for expansion and contraction.

The value of tin roofing-plate is dependent upon five things: 1st. The quality of the material of which the plate is made.

The best plates for tinning are of charcoal-iron, which, being tough, bears bending. Coke-iron is used for cheaper plates. It is inferior as regards bending. Open-hearth and Bessemer steel plates are now generally used in place of iron. The former is used for the better grades, the latter for inferior grades.

2d. The coating, whether it is tin or a mixture of tin and lead; the latter is not so durable as the former. The thickness of the coating; this can be determined by trying with a knife.

3d. The net weight of the hundred and twelve sheets in the box. The standard weight of an ordinary IC 14 × 20 inch plate is 108 pounds to the 112 sheets, but there are many boxes imported that run all the way from 90 to 120 pounds in weight. The standard weight of a box of IX 14″ × 20″ is 136 pounds, and of IX 20″ × 28″, 272 pounds. There are IX 14 × 20 plates imported that do not weigh over 120 pounds per box, while others weigh as much as 150 pounds for the same size. It may be that the lighter sheets have as heavy a coating of lead and tin as the heavier sheets, but the possibility is that they have not. The quantity of tin required for coating 112 sheets of 14″ × 20″ IC plate is 3¼ lbs., but as low as 2¼ lbs. are said to be used. The amount of tin used in coating the plates is very irregular; a few years ago 7 lbs. to the box was considered the average, but now as little as 2 lbs. per 100 lbs. of iron is used.

4th. The squareness of the sheets.

5th. The assortment of the sheets. In the manufacture of tin plates there occur imperfect sheets, having corners and edges broken, spots not covered with tin, etc. These are packed by themselves in separate boxes, and denominated as "wasters," while the perfect sheets are denominated "prime" plates. The boxes containing "wasters" or imperfect sheets are marked "ICW" or "IXW," according to the thickness; so that where the letter "W" appears on a box it shows that the box contains imperfect sheets, and should not be accepted when "prime" tin is specified.

It is now becoming the custom to stamp every sheet with the name of the brand and thickness before leaving the factory.

Table 18.

TIN PLATES (TINNED SHEET STEEL).

BRAND.											
	IC	IX	IXX		IC	IX	IXX	IXXX	IXXXX	IX	IXX
THICKNESS, B. W. GAUGE.											
	29	27	26		29	27	26	25	24½	27	26
NUMBER OF SHEETS PER BOX.											
	225	225	225		112	112	112	112	112	56	56
NET WEIGHT PER BOX.											
Size. Inches.	Pounds.			Size. Inches.	Pounds.						
10 × 14	108	135	160	14 × 20	108	135	160	180	200		
12 × 12	110	138	165	20 × 28	216	270	320	....	....	180	
13 × 13	132	162	192	18 × 18	138	158	178				
14 × 14	155	193	230	20 × 20	160	195	222				
15 × 15	178	218	260	22 × 22	190	235	275				
16 × 16	200	248	290	24 × 24	220	276	330				
17 × 17	230	289	340	12 × 24	110	138	165				
10 × 20	160	195	222	13 × 26	132	162	192				
11 × 22	190	235	275	14 × 22	120	148	174				
				14 × 24	130	161	190				
				14 × 28	155	193	230				
				14 × 56	...	...	...	....	....	185	220
				14 × 31	178	210	240				
				14 × 60	...	...	...	....	....	200	240
				15 × 21	120	152	176				
				16 × 19	120	147	170				
				16 × 20	127	154	180				
				16 × 22	138	170	200				

BRAND.					
	DC	DX	DXX	DXXX	DXXXX
THICKNESS, B. W. GAUGE.					
	28	25	24	23	22
NUMBER OF SHEETS PER BOX.					
	100	100	100	100	100
NET WEIGHT PER BOX.					
Size. Inches.	Pounds.				
12¼ × 17	94	122	143	164	185
15 × 21	130	180	218	244	275
NUMBER OF SHEETS PER BOX.					
17 × 25	50 / 94 lbs.	50 / 122 lbs.	50 / 143 lbs.	50 / 164 lbs.	50 / 185 lbs.

Terne plates, 112 sheets per box	10″ × 20″ IC, 80 lbs.; IX, 100 lbs. 14 × 20 IC, 112 " IX, 140 " 20 × 28 IC, 224 " IX, 280 "
Taggers tin and iron, 36 and 38 B. W. G.	10 × 14 and 14 × 20, 112 lbs. per box.

The a ea of roof covered by any sheet is less by 2 inches in width and 1 inch in length than the proposed sheet.

TABLE 19.

WEIGHT OF SHEETS OF WROUGHT IRON AND STEEL.

WEIGHTS PER SQUARE FOOT. THICKNESS, BIRMINGHAM GAUGE.

No. of Gauge.	Thickness. Inches.	Iron.	Steel.
0000	.454	18.22	18.46
000	.425	17.05	17.28
00	.38	15.25	15.45
0	.34	13.64	13.82
1	.3	12.04	12.20
2	.284	11.40	11.55
3	.259	10.39	10.53
4	.238	9.55	9.68
5	.22	8.83	8.95
6	.203	8.15	8.25
7	.18	7.22	7.32
8	.165	6.62	6.71
9	.148	5.94	6.02
10	.134	5.38	5.45
11	.12	4.82	4.88
12	.109	4.37	4.43
13	.095	3.81	3.86
14	.083	3.33	3 37
15	.072	2.89	2.93
16	.065	2.61	2.64
17	.058	2.33	2.36
18	.049	1.97	1.99
19	.042	1.69	1.71
20	.035	1.40	1.42
21	.032	1.28	1.30
22	.028	1.12	1.14
23	.025	1.00	1.02
24	.022	.883	.895
25	.02	.803	.813
26	.018	.722	.732
27	.016	.642	.651
28	.014	.562	.569
29	.013	.522	.529
30	.012	.482	.488
31	.01	.401	.407
32	.009	.361	.366
33	.008	.321	.325
34	.007	.281	.285
35	.005	.201	.203
Sp. gr.		7.704	7.806
Wt. cu. ft. . .		481.25	487.75
" " in. . .		.2787	.2823

Zinc.

Zinc is obtained from the carbonate, sulphide, and red oxide ores. The ore is roasted, mixed with charcoal, and heated in retorts. The zinc is converted into vapor, which is condensed and subsequently fused.

Zinc is a rather hard, bluish-white metal, tough and not easily broken by blows of the hammer at ordinary temperatures, but when heated to a point approaching that of fusion it becomes brittle. At temperatures between 210° and 300° F. it is ductile and malleable, and may be rolled into sheets, and drawn into moderately fine wire, which, however, possesses but little tenacity.

Properties of Zinc.

Specific gravity	7.14
Weight per cubic foot, cast	428 lbs.
Melting-point, 780° F.; volatilizes and burns in the air when melted with bluish-white fumes of zinc oxide.	
Atomic weight	65
Specific heat	.096
Conductivity of heat	36
" " electricity	29 (silver being 100)
Tenacity	5000 to 6000 lbs. per. sq. in.
Expansion between 32° and 212° F.	0.0088

Zinc is used for making brass and other alloys, and for coating iron surfaces, called "galvanizing."

For the purpose of galvanizing the iron is dipped into dilute sulphuric acid to remove scale, etc., and then plunged into a bath of molten zinc covered with sal-ammoniac.

Combined with copper it forms brass, and with the addition of tin and other metals various similar alloys are formed, which are distinguished by specific names.

Zinc forms the base of the zinc paints.

Zinc should not be used in contact with copper, iron, or lead, as voltaic action is set up, especially when moisture is present, thus destroying the zinc. Soot, lime, water containing lime, and acid woods, such as oak, are also very destructive of it. When first exposed to the action of the atmosphere it is speedily corroded, but the film of carbonate of zinc thus formed protects it from further oxidation.

Good sheet zinc is of an uniform color, tough and easily bent backwards and forwards without cracking.

Inferior zinc is of a darker color than the pure metal and of a blotchy appearance, caused by the presence of other metals, which set up a galvanic action and soon destroy the zinc.

Alloys.

The term alloy is generally applied to all combinations obtained by fusing metals with each other, except when mercury is one of the combining metals, in which case the compound is called *amalgam*. Many of the alloys are importantly useful, as brass, bronze, etc.

The specific gravity of alloys does not follow the ratio of that of their components; it is sometimes greater and sometimes less than the mean, showing that in some cases expansion has taken place, and in others contraction.

Brass is an alloy of copper and zinc, in proportions varying with the purpose for which the metal is required. The color is dependent upon the proportions. It is rendered brittle by continued impacts, is more malleable than copper when cold, is impracticable of being forged, as its zinc melts at a low temperature. Its malleability is decreased as the proportion of zinc is increased. Its tenacity is impaired by the addition of lead or tin. Its fusibility is governed by the proportion of zinc.

Bronze is a mixture of copper and tin, the proportions being varied for different purposes. Large castings in bronze are often not homogeneous throughout their mass in consequence of the difference in fusibility of the copper and tin.

Aluminum Bronze is composed of from 90 to 95 per cent of copper and 10 to 5 per cent of aluminum.

Phosphor Bronze is any bronze or brass alloy with a small proportion of phosphorus.

Manganese Bronze is an alloy of pure copper with from 2 to 30 per cent of manganese. Its color is usually white.

Table 20.

ALLOYS AND COMPOSITIONS.

*	Cu	Zn	Sn	Ni	Pb	Sb	Bi	Al
Argentan	55	24	....	21	....	....	....	...
Aluminum, brown	95	....	....	....	....	....	....	5
Babbitt's metal	3.7	....	89	....	....	7.3	....	....
Brass, common	84.3	5.2	10.5	....	....	....	....	....
" "	75	25	...	....	....	....	....	....
" " hard	79.3	6.4	14.3	....	...	....	...	....
" instruments	92.2	....	7.8	....	....	....	....	....
" locom. bearings	90	1	9	....	....	....	....	....
" Pinchbeck	80	20	....	....	....	....	....	....
" red Tombac	88.8	11.2	....	....	....	....	....	....
" rolled	74.3	22.3	3.4	....	....	....	....	....
" Tutenag	50	31	....	19	....	...	....	....
" very tenacious	88.9	2.8	8.3	....	....	....	....	....
" wheels, valves	90	....	10	..	....	....	....	..
" white	10	80	10	....	....	....	....	....
" "	3	90	....	....	....	7	....	....
" "	7	....	....	....	46	47	....	....
" wire	67	33	....	....	....	..	....	....
" yellow, fine	66	34	....	....	....	....	...	....
Britannia metal	....	....	25	....	....	25	...	....
When fused add	.....	.....	.....	.....	.....	25	25	.....
Bronze, red	87	13	....	....	....	....	....	...
" "	86	11.1	2.9	....	....	....	....	....
" yellow	67.2	31.2	1.6	....	....	....	....	
" gun-met., large	90	....	10	....	....	....	....	
" " " small	98	...	7	..	....	...	....	
" " " soft	95	....	5	....	....	....	....	
" cymbals	80	....	20	....	....	...		
" medals	93	....	7	....	....	....		
" phosphor	92	....	8	....	....	....		
" "	90	....	10	....	....	....		
" statuary	91.4	5.5	1.4	...	1.7	....		
Bush-metal	16	1	1	...	1	...		....
Chinese silver	58.1	17.2	....	11.6	....	....	Silver 2	Cobalt of Iron 11.1
" white copper	40.4	25.4	2.6	31.6	...	....	....	....
Church-bells	80	5.6	10.1	....	4.3	....	....	
" "	69	....	31	....	....	....	....	
Clocks, musical bells	87 5	....	12.5	....	....	....	....	....
Clock-bells	72	...	26.5	...	....	....	....	Iron 1.5
German silver	33.3	33.4	....	33.3	...	....	....	....
" "	40 4	25.4	....	31.6	....	....	....	2.6
" " fine	49.5	24	....	24	....	....	...	2.5
Gongs	81.6	...	18.4	....	....	....	...	....
Gun-metal	90	3	9	....	....	....	....	....
House-bells	77	....	23	....	....	....		....
Lathe-bushes	80	....	20	....	....	....		....
Machinery bearings	87.5	....	12.5	....	....	....		...
" " hard	77.4	7	15.6	....	....	....		...
Metal that expands in cooling	....	....	....	....	75	16.7	Bismuth 8.3	....
Muntz metal, 10 oz. lead	60	40	...	....	....	....	...	
Pewter, best	....	....	86	....	....	14	....	
"	....	....	80	...	20	....	....	
Sheathing-metal	56	45	....	....	....	....	....	....
Speculum "	66	....	22	....	....	....	....	Arsen. 12
" "	50	21	29	....	....	....	....	....
Steam-metal	86	4	6	...	4	....	....	....
Telescopic mirrors	66.6	....	33.4	....	....	....	....	....
Temper	33.4	....	66.6	....	....	....	....	....
Type-metal and stereotype plates	....	....	....	....	75	25	...	....
	....	....	....	....	87.5	12.5	....	....
White metal	7.4	7.4	28.4	....	....	56.8	....	....
" " hard	69.8	25.8	4.4	....	....	....	....	....
Oreide	73	12.3	Magnesia.....4.4 Sal-am'niac..2.5			Cream of tartar..6.5 Quicklime.......1.8		

* Cu = copper; Zn = zinc; Sn = tin; Ni = nickel; Pb = lead; Sb = antimony; Bi = bismuth; Al = aluminum.

Solders.

Solder is the name given to several different alloys used for the purpose of making joints between pieces of metal.

The composition of the solder used in connection with the different metals varies immensely, and the proportions in which each different kind of solder is mixed also vary according to circumstances.

Solder must be more fusible than the metals it is intended to unite.

Hard solders are those which fuse only at a red heat.

Soft solders melt at a very low degree of heat.

TABLE 21.

COMPOSITION OF SOLDER.

Melting-point.	Name or Use.	Tin. Parts.	Lead. Parts.	Zinc. Parts.	Bismuth. Parts.	Brass. Parts.	Pewter. Parts.	Copper. Parts.
482° F.	Plumbers', coarse (hard)	25	75	...	....	....	....	..
350 "	" fine (soft)......	67	33	....	...	....	....	..
372 "	" fusible	50	50	....	....	....	....	..
200 "	" very fusible...	25	25	....	50	....	....	..
	For brass...............	....	....	33	....	67	....	..
	" tin..................	16½	....	....	16½	....	67	..
	" "	25	75	....	....	....	....	..
	" copper..............	47	....	....	....	....	....	53
	" " (hard)........	....	....	33	....	....	....	67

Soldering.—The surfaces to be united must be perfectly clean and freed from oxide, which would prevent adhesion and the formation of an alloy between the solder and the metal.

As the surfaces when heated are very easily oxidized, they must be protected at the time. This is done by means of a *flux* which covers the surface and protects it from the air.

Fluxes for Soldering.—The flux is varied according to the metals to be united.

Metals.	Fluxes.
Copper and brass..........	Sal-ammoniac, chloride of zinc, or rosin
Tinned iron..............	Chloride of zinc or rosin
Zinc......................	Chloride of zinc
Lead.....................	Tallow or rosin
Lead and tin..............	Rosin and sweet oil

Soldering-fluid is a concentrated solution of chloride of zinc.

Tests for Materials.

The tests to which materials used for specific purposes are subjected are ordinarily as follows:

AXLES.—Drop test, with tension test if further knowledge is desired.

BOILER IRON.—*Plates* by tension, forging, and punching tests, and bending cold and hot. *Shapes*, the same, with welding test if shape is to be welded in use. *Rivets*, by tension, bending, and forging.

BOILER STEEL.—Tension, hardening, and forging tests, and bending hot and cold.

HIGH STRUCTURAL STEEL.—Tension, bending, and hardening.

MILD STRUCTURAL STEEL.—Tension and bending tests, with welding, hardening, and annealing test if the metal is to be used for welded members.

STRUCTURAL IRON.—Tension, bending, and welding tests.

SHIP MATERIAL.—*Plates*, tension and cold bending tests. *Shapes*, tension and hot and cold bending tests. *Rivets*, tension, bending, and forging tests.

RAILS.—Drop test and bending test, with tension test if further information is desired.

TIRES.—Drop test, with tension test for further knowledge.

WIRE.—Tension and winding tests, and tests by bending back and forth around a turned stud of same diameter as the wire.

WIRE ROPE.—Tension and longitudinal impact tests.

STEEL PINS.—Test-specimens are usually cut from the ends of blooms which have been forged into sizes convenient for the purpose. Tested by tension and bending. Pins of over 6 inches in diameter are in most cases drilled through their larger axis with holes from $\frac{1}{8}$ inch to $1\frac{1}{8}$ inches in diameter, for the purpose of testing the soundness through the entire length.

BOLTS AND RIVETS.—Tension, shearing, and forging tests.

CAST IRON.—Tension, bending, and compression tests.

COPPER ALLOYS AND SOFT METALS.—Tension and compression tests.

WOODS.—Tension, compression, and transverse tests.

CEMENTS AND MORTARS.—Tension and compression tests.

BUILDING BRICKS AND STONES.—Compression and transverse tests.

PAVING BRICKS AND STONES.—Compression, transverse, impact, and abrasion tests.

Testing Strength of Materials.

The tests to which structural materials are subjected in order to ascertain their strength or resistance to deformation when in use are: tests for compression, or resistance to crushing; tension, or resistance to tearing asunder; and flexion, or resistance to breaking under transverse strain.

The testing is performed in suitable machines provided with apparatus for measuring the force of the required stress. Several forms of these machines are in the market and descriptions can be obtained from the manufacturers.

The preparing of the specimens, carrying out the test, and interpreting the results require great care and study to avoid the reaching of erroneous conclusions, and should not be undertaken by those not thoroughly acquainted with the subject and with the particular material to be tested.

The testing-machine should be tested to determine whether its weighing apparatus is accurate, and whether it is so made and adjusted that in the test of a properly made specimen the line of strain is absolutely in line with the axis of the specimen. If it is not the result will be erroneous, because, the stress not being uniformly distributed on the cross-section, one side will have to yield prematurely, and thus the resistance of the specimen will be overcome in detail; for want of attention to this particular many tests do not afford reliable results.

The speed with which the load is applied is an important element and should be carefully noted and recorded.

In tensile tests wrought iron and soft steel can be made to show a higher strength by keeping them under strain for a greater length of time. The pulling speed should not be less than half an inch per minute and not more than three inches per minute.

In testing soft alloys—copper, tin, zinc, and the like—which flow under constant strain their highest apparent strength is obtained by testing them rapidly.

Test-specimens.—In determining the size of the specimens for tensile tests the strength of the machine must first be taken into account. It is extremely convenient and it simplifies the subsequent calculation to make them of such a size that their sectional area will be a convenient multiple or fraction of a square inch.

Tension.—The form of test-piece generally adopted for flat bars, plates, and shapes is a parallel strip which varies in length

according to the capacity of the machine on which it is to be tested. The ends are T-shaped by cutting fillets with a radius of about half an inch, so that the jaws of the machine can take a firm grip. In some cases the specimens are turned in a lathe to the required dimensions and forms. The section should be uniform for not less than five inches of its length.

The data obtained from a tensile test are: 1. Tensile strength in pounds per square inch of original area. 2. Elongation per cent of a stated length between gauge-marks, usually 8 inches. 3. Elastic limit in pounds per square inch of original area.

In order to be able to compare records of elongation it is necessary not only to have a uniform length of section between gauge-marks, but to adopt a uniform method of measuring the elongation to compensate for the difference between the apparent elongation when the piece breaks near one of the gauge-marks and when it breaks midway between them. The following method is recommended (Trans. A. S. M. E., Vol. XI, p. 622):

Mark on the specimen divisions of ½ inch each. After fracture measure from the point of fracture the length of eight of the marked spaces on each fractured portion (or 7 + on one side and 8 + on the other if the fracture is not at one of the marks). The sum of these measurements, less 8 inches, is the elongation of 8 inches of the original length. If the fracture is so near one end of the specimen that 7 + spaces are not left on the shorter portion, then take the measurement of as many spaces (with the fractional part next to the fracture) as are left, and for the spaces lacking add the measurement of as many corresponding spaces of the longer portion as are necessary to make the 7 + spaces.

During the performance of the test the operator has to watch carefully the behavior of the specimen in order to note its general character. Special care is required to note the reaching of the elastic limit, or the point at which the rate of stretch or other deformation begins to increase. When this point is reached the future behavior of the material will altogether depend on its precise nature. If it is of a soft and ductile nature it will be drawn out to a small diameter in the neighborhood of the point of fracture before the final rupture takes place. If it is hard and rigid it may not be drawn out to any great extent, but may break, with very little reduction of area, and exhibit a high tenacity.

As the critical point is being approached the utmost care has to be observed to avoid rashness in the application of the weight and to secure reliable results.

Compression.—Specimens for ascertaining the resistance to compression are generally made in the form of cylinders, cubes, or rectangular prisms with square ends, of such dimensions as can be overcome by the power of the testing-machine.

The dimensions of the specimen and its behavior, i.e., how it splits or fractures, bulges, bends, buckles, or flattens, and the loads which produce such effects, are noted.

Transverse Strength.—Tests for resistance to transverse strain are made on prismatic bars, whose ends rest on knife-edges, and have a strain imposed at the centre, either by loading a plate suspended on a knife-edge or by means of levers.

The dimensions of the specimen, distance between supports, deflection, and breaking weight are the points to be noted.

Impact or Drop Tests are applied on full-sized specimens by means of a weight falling through a given distance (usually a weight of one ton falling through a distance of from 20 to 30 feet). The number of blows required to cause rupture, the behavior of the material under the blows, the character of the fibre, and the contraction of area are noted. The specimen is so arranged that the blows act in the direction of its length.

Contraction or Shrinkage of Metals.

The allowance necessary for shrinkage varies for different kinds of metal and the different conditions under which they are cast. For castings where the thickness runs about one inch, cast under ordinary conditions, the following allowance can be made:

For cast iron	$\frac{1}{8}$	inch per foot
" " brass	$\frac{3}{16}$	" " "
" " copper	$\frac{3}{16}$	" " "
" " steel	$\frac{1}{4}$	" " "
" " lead	$\frac{5}{16}$	" " "
" " malleable iron	$\frac{1}{8}$	" " "
" " zinc	$\frac{5}{16}$	" " "
" " tin	$\frac{1}{12}$	" " "
" " aluminum	$\frac{3}{16}$	" " "
" " britannia	$\frac{1}{32}$	" " "

Thicker castings under the same conditions will shrink less and thinner ones more than this standard. The quality of the material and the manner of moulding and cooling will also make a difference.

To compute Weight of Cast Metals by Weight of Pattern.—Multiply weight of pattern by the following coefficients:

Cast Iron.

Pattern made of	Coefficient.
White pine	14
Oak	9
Beech	9.7
Birch	10.6
Linden	13.4
Alder	12.6
Pear	10

Brass.

White pine	15

Lead.

White pine	22

Tin.

White pine	14

Zinc.

White pine	13.5

Very accurate results cannot be expected, as the specific gravity of wood as well as of the metal fluctuates.

Reductions for Round Cores and Core-prints.—Multiply the square of the diameter by the length of the core in inches, and the product by 0.017 is the weight of the pine core to be deducted from the weight of the pattern.

WEIGHT OF CASTINGS DETERMINED FROM WEIGHT OF PATTERN.

A Pattern Weighing One Pound made of	Will Weigh when Cast in				
	Cast Iron.	Zinc.	Copper.	Yellow Brass.	Gun-metal.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Mahogany, Nassau	10.7	10.4	12.8	12.2	12.5
" Honduras	12.9	12.7	15.3	14.6	15.0
" Spanish	8.5	8.2	10.1	9.7	9.9
Pine, red	12.5	12.1	14.9	14.2	14.6
" white	16.7	16.1	19.8	19.0	19.5
" yellow	14.1	13.6	16.7	16.0	16.5

VII. Miscellaneous Materials.

Sand.

Sand is an aggregation of loose, incoherent grains of a crystalline structure, derived from the disintegration of rocks and other mineral matter. It is called "silicious," "argillaceous," or "calcareous," according to the character of the rock from which it is derived. It is obtained from pits, beds of rivers, the seashore, or may be made by grinding sandstones. The sand derived from the quartzose rocks is the most preferred for building purposes. As substitutes for sand, scoriæ, slag, cinder, and burnt clay are frequently used.

Pit-sand has an angular grain and a somewhat rough surface, but often contains clay and organic matter; when washed and screened it furnishes a good sand for general purposes.

River-sand has more or less rounded grains, and may or may not contain clay or other impurities. It is commonly of fine grain, is often white in color, and when clean is suited for plastering.

Sea-sand has also more or less rounded grains. It contains alkaline salts, which attract and retain moisture and cause efflorescence when used in brick masonry.

Both sea- and river-sand are deficient in the sharpness required for good mortar on account of the attrition they are exposed to, but they are suitable for plastering, and in many localities the lack of more suitable material obliges their use for mortar, in which case they should be thoroughly washed.

Use of Sand.—The uses of sand are various, as for mortar, for distributing the pressure of structures in soft soils, as a foundation and joint-filling for block and brick pavements, as piles in foundations, for plaster, etc.

The use of sand in mortar is to prevent excessive shrinkage, and to save the cost of lime or cement. Ordinarily it is not acted upon by lime, its presence in mortar being purely mechanical. Rich lime adheres better to the surface of sand than to its own particles, hence it is considered to strengthen lime mortar. With cement it weakens the mortar.

Size of Sand.—When the grains of sand range from $\frac{1}{16}$, to $\frac{1}{8}$ inch it is called "coarse" sand; when from $\frac{1}{16}$ to $\frac{1}{32}$, "fine" sand; and from $\frac{1}{30}$ to $\frac{1}{60}$ "very fine" sand; and when composed of sizes varying within these limits, "mixed" sand.

The Fineness of sand is measured by passing through sieves having the following dimensions;

Table 22.

SIZE OF SIEVES FOR SIFTING SAND

Number of Sieve.	Number of Holes per Lineal Inch.	Number of Holes per Square Inch.	Length of Side of Hole. Inch.	Diameter of Wire. Inch.
1	20	400	.03101	.01899
2	30	900	.02119	.01214
3	50	2500	.01119	.00881
4	80	6400	.00599	.00051
5	170	28900	.00309	.00279

Weight of Sand.—Dry sand weighs from 80 to 115 pounds per cubic foot, or about one to one and a half tons per cubic yard.

The Voids of ordinary sand range from 0.3 to 0.5 of the volume. The more uneven the grains in size the smaller the percentage of voids.

Testing Sand.—The Cleanness of sand may be tested by rubbing a little of the dry sand in the palm of the hand, and after throwing it out noticing the amount of dust left on the hand. The cleanness may also be judged by pressing the sand between the fingers while it is damp; if the sand is clean it will not stick together, but will immediately fall apart when the pressure is removed.

The Sharpness of sand can be determined approximately by rubbing a few grains in the hand or by crushing it near the ear and noting if a grating sound is produced; but an examination through a small lens is better.

To determine the Presence of Salt and Clay.—Shake up a small portion of the sand with pure distilled water in a perfectly clean stoppered bottle, and allow the sand to settle; add a few drops of pure nitric acid and then add a few drops of solution of nitrate of silver. A white precipitate indicates a tolerable amount of salt; a faint cloudiness may be disregarded.

The presence of clay may be ascertained by agitating a small quantity of the sand in a glass of clear water and allowing it to

stand for a few hours to settle; the sand and clay will separate into two well-defined layers.

Preparation of Sand.—SCREENING.—Sand is prepared for use by screening to remove the pebbles and coarser grains. The fineness of the meshes of the screen depends upon the kind of work in which the sand is to be used.

WASHING.—Sand containing loam or earthy matters is cleansed by washing with water, either in a machine specially designed for the purpose and called a sand-washer, or by agitating with water in tubs or boxes provided with holes to permit the dirty water to flow away.

DRYING.—When dry sand is required it is obtained by evaporating the moisture either in a machine called a sand-dryer, or by heating the sand in large shallow pans of wrought iron or on sheets of boiler-plate supported on stones with a wood fire placed underneath.

Gravel.

Gravel is an accumulation of small rounded stones which vary in size from a small pea to a walnut or something larger. It is often intermingled with other substances, such as sand, loam clay, etc., from each of which it derives a distinctive name.

The uses of gravel are various, as: for concrete, for lining at the back of retaining walls and slope pavements, as a filling with bituminous cement for the joints in block pavements and for tar and asphalt roofs, etc.

For use it is assorted into different sizes by screening and when necessary washed.

WEIGHT OF GRAVEL.—A cubic yard of pit-gravel weighs about 3300 pounds; mixed with clay it weighs about 155 pounds per cubic foot.

Shingle is the small stones found on the shores of rivers or the sea.

Grit is fine gravel, the pebbles of which do not exceed one half inch in diameter. The name grit is also applied to hard sandstone.

Clay.

Pure clay consists of a hydrated silicate of alumina in combination with other substances derived from the felspathic rocks, which by their disintegration and decomposition have formed clay. The purest form of clay containing the largest proportion of alumina is known as *kaolin,* the name of a mountain in China where a pure white clay is worked; it is a pure white, dull, earthy, unctuous substance.

Pure clay is soft, more or less unctuous to the touch, white and opaque, and when breathed upon emits a characteristic odor. It is infusible and insoluble either by water, nitric or hydrochloric acid. It may be converted by water into a doughy, tenacious, plastic mass. It absorbs water with avidity, but when burned at a sufficiently high temperature it becomes hard and brittle and loses almost wholly or altogether this property of combining with water.

In nature the greater number of clays are found intermingled with other substances foreign to them in their original localities.

The usual constituents of clay are alumina, silica, iron, lime, magnesia, and alkalies, all of which modify the character of the clay and its applications, according as one or other of these ingredients predominates.

Clay and sand mechanically mixed constitute *loam;* clay and carbonate of lime mechanically mixed, *marl.*

Clay is of various colors, as red, blue, brown, yellow or ochre, and variegated. The color is due to the presence of metallic oxides, usually iron and some organic substances.

Refractory Clays are those which resist fusion by the greatest heat of an ordinary furnace. They consist mainly of alumina and silica, the silica predominating. They are used for the manufacture of fire-bricks and crucibles.

Gypsum—Plaster of Paris.

Gypsum is a compound of sulphate of lime with water. It is found stratified and in various conditions: crystalline, laminated, granular, and earthy. It is translucent, usually white or gray, has a pearly lustre, and can be easily scratched with a knife.

By calcining gypsum the water is expelled, and it becomes a dry white powder of sulphate of lime, known as "plaster of Paris." When this powder is rapidly mixed with water so as to form a paste it immediately begins to combine with a part of the water, so as to reproduce gypsum in a compact granular state; heat is at the same time developed, which hastens the evaporation of the superfluous water. The mixture should be made by putting the powder into the water, not the water amongst the powder.

The principal use of plaster of Paris is for plastering and interior decoration. (See under Plastering.)

Mineral Wool.

Mineral wool, slag wool, or silicate cotton is a glass-like fibre produced from blast-furnace slag. The process consists in subjecting a small stream of the molten slag to the force of a jet of steam or compressed air, which divides it into innumerable small shot or spherules, forming a spray of spark-like objects. Threads are formed and detached from the main body of the stream, their length and fineness being dependent upon the fluidity and composition of the material under treatment. When the slag is of the proper consistency the spherules are small at the outset, and are to some extent absorbed into the fibre, but in no case will they entirely disappear; so that a great portion of the wool contains them they are separated by riddling. That portion of the thread which is carried away and separated from the shot by the air-currents is very light, weighing about 14 pounds per cubic foot, and forms the grade called "extra" grade; the balance of the fibre weighs about 24 pounds per cubic foot, and is called "ordinary" grade. A cubic foot of the slag weighs about 192 pounds. In the manufacture of mineral wool slags of a slightly acid composition are preferred, though it is said that any scoriaceous substances can be used.

When gathered up the threads and fragments appear to lie in all possible directions with relation to each other, in consequence

of which there is no parallelism or common direction to the threads, so that the air-spaces are angular in shape and microscopic in size. The wool is collected in a large chamber, where it settles in a bulky state, having a fleecy appearance. About 80 per cent of the product has to be riddled.

The fibres or threads vary in thickness from that of common spun glass to an extreme tenuity, represented by fractions of a thousandth of an inch. The bulbs may be generally described as solid bodies containing more or less numerous vesicles or hollows; the more solid ones are transparent or show iridescence.

Mineral wool is fire- and vermin-proof, and is used for insulating heated surfaces, for protection against cold, deadening sound, fire-proofing, vermin-proofing, and for cleaning galvanized wire, etc. It is applied loose. But, although one of the most valuable non-conducting substances, it requires to be used with precaution against the absorption of moisture, in which case it is liable to decompose, the sulphur originally contained in the slag oxidizing to sulphuric acid, and forming soluble sulphates, which attack the metallic surfaces with which the wool is in contact. It has been found that not only the mineral acids, but also organic acids, are capable of decomposing it in the presence of moisture and heat, and the fine fibrous condition of the wool renders it still more subject to decomposition than solid slag. As the non-conducting property depends upon the interstitial air-space, it is essential that it should not become packed.

One ton will cover about 1800 square feet one inch thick.

"Extra" grade is put up in bags containing from 25 to 45 pounds; each; "ordinary" grade is put up in bags containing from 60 to 90 pounds.

Asbestos.

Asbestos is a fibrous mineral composed principally of silica and magnesia. It consists of fine crystalline fibres which vary greatly in character, being sometimes of a long staple or fibre, and sometimes flocculent or like woody fibre, or resembling clay or soapstone, or even in a granular form. In color it ranges from white with greenish and metallic reflections through many shades of yellow to dull brown or reddish. The reddish varieties appear to be colored with an admixture of oxide of iron. The most valuable property of asbestos is its power to resist high temperatures, which is indicated by its name "unconsumable." Some varieties are unaffected by a heat up to 2000° F. Other kinds can only be fused at 3000° F., and some kinds have been submitted to a temperature of 5000° F. without apparent change. Some kinds when heated to a sufficient temperature to drive off the contained water become brittle and may easily be crumbled between the finger and thumb. As a rule it fuses with difficulty before the blowpipe. It feels soft and greasy to the touch, like soapstone or talc, but is clean, and in the form of flour can be rubbed away between the fingers to an invisible powder.

The mineral when consisting of long, tough, and flexible fibres is usually distinguished from the commoner varieties of asbestos by the name "chrysotile." Such material is used for weaving into fabrics.

Tar.

COAL-TAR is produced as a by-product in the manufacture of gas from coal. When distilled it produces, in various stages, first, *coal-naphtha*, which is useful for dissolving rubber, etc.; then *dead-oil* or *creosote*, used for preserving timber ; and lastly, *tar* or *pitch*, which is used for roofing, waterproofing walls, etc., and as an ingredient for varnishes, and for filling the joints in stone-block pavements, coating cast-iron pipes, etc.

Coal-tar is very brittle at the freezing-point and softens and flows between 70° and 115° F. It has a strong pungent odor.

Paving Pitch, used for filling joints in stone-block pavements, etc., is the residue obtained from distilling coal-tar, and is designated as Distillate No. 1, 2, 3, etc., according to its density or specific gravity. The character of the distillate varies with the system and temperature employed.

WOOD-TAR is produced by the distillation of pine and other resinous trees; the residue left after distillation is called *pitch*.

MINERAL TAR is obtained by distilling bituminous shales (see Asphaltum).

Creosote.

Creosote oil is a product obtained in distilling coal-tar. It is an oily liquid, varying in composition according to the quality of the coal from which it is obtained, and containing hydrocarbons of different degrees of volatility and varying antiseptic qualities.

The requisites for creosote oil used in the preservation of timber are:

To contain 8 per cent of tar acids by analysis with caustic soda and sulphuric acid.

To be quite liquid at 100° F. and without deposit until the temperature falls to 95° F.

One fourth not to distil over in a retort at less temperature than 600° F., and this fourth to be heavier than water.

To be free from adulteration with bone-oil, shale-oil, or any oil not distilled from coal-tar.

The minute glistening cubes generally observable on freshly creosoted wood consist of naphthaline, a substance that possesses considerable antiseptic properties; when this substance exists in the liquid creosote in moderate quantities it thickens and confirms its consistency, but when there is a very large proportion it makes the creosote too solid.

WOOD-CREOSOTE OIL is a product of the distillation of wood tar obtained from the resinous woods, as Georgia pine, etc. It has a specific gravity of about 1.05, is still fluid at 15° F., boils at 230° F., contains 5 per cent of tar, 45 per cent of tar acids, 50 per cent oils, has a peculiar penetrating odor and hot taste.

Patented preparations of wood creosote, sold under the names of *fernoline*, *woodiline*, etc., are extensively used as a preservative for wood.

Sheathing-felts and -papers.

FELT.—The better qualities of felt are made from hair cemented together with asphaltic cement; the commoner varieties are composed of waste vegetable fibres cemented together with asphaltum, coal-tar, or rosin.

ASPHALT FELT is prepared by saturating felt with asphaltum either alone or mixed with petroleum residuum. It is black or nearly black in color and has a strong odor of asphaltum.

TAR FELT is prepared by saturating felt with coal-tar.

ASBESTOS FELT is prepared from fibrous asbestos cemented together with various cementing materials.

PAPERS.—Sheathing-papers are made from Manila hemp and other vegetable substances treated with various compounds (such as certain compounds of copper and ammonia), the effect of which is to coat and impregnate them with a varnish-like substance (cupro-cellulose) which enables them to resist the weather.

The papers are made in one, two, or three thicknesses and are designated as "one-ply," "two-ply," etc.

The cheaper grades of paper are made waterproof by saturating them with various rosins and some earthy material as a filler. Waste oils are also used.

ASBESTOS PAPER is manufactured from asbestos cemented by various cementing materials.

TARRED PAPER is prepared by saturating Manila or other paper in coal-tar alone or mixed with lime and residuum oils.

ROSIN-SIZED PAPERS are made by immersing Manila or other paper in a mixture of rosin, glue, and ochre.

Glue.

Glue is prepared from waste pieces of skins, horns, hoofs, and other animal offal.

These are steeped, boiled, strained, melted, reboiled, and cast into cakes, which are then dried.

The strongest kind of glue is made from the hides of oxen, that from the bones and sinews is weaker; the older the animal the stronger the glue.

Good glue should be hard in the cake, of a strong dark color, almost transparent, free from black or cloudy spots, and with little or no taste or smell.

The best varieties are transparent and of a clear amber color.

Inferior kinds are sometimes contaminated with the lime used for removing the hair from the skins of which they are made.

The best glue swells considerably (the more the better) when immersed in cold water, but does not dissolve, and returns to its former size when dry.

To prepare glue for use it should be broken up into small pieces, and soaked in as much cold water as will cover it for about twelve hours.

It should then be melted in a double glue-pot, covered, to protect the glue from dirt. Care must be taken that the outer vessel is full of water, so that the glue shall not burn or be brought to a temperature higher than that of boiling water.

The glue should be allowed to simmer for two or three hours, then gradually melted; then a small quantity of boiling water is added to make the glue liquid enough to run off a brush in a continuous stream without breaking into drops.

Freshly melted glue is stronger than that which has been repeatedly remelted.

Frequent remelting impairs the quality of the glue. This may be known to be the case when it becomes of a dark and almost black color.

To secure the full effect of the adhering qualities of glue it is necessary that it be thoroughly melted and used while boiling hot; that the wood to be united be perfectly clean, dry, and warm; that the surfaces of each piece be covered evenly with a thin film and then brought together as tightly as possible, so that the superfluous glue may be squeezed out.

Rope.

Rope is the general name applied to cordage over one inch in circumference.

The materials employed for making rope are various vegetable fibres. The strongest rope is made of hemp, Manila hemp and sisal hemp. For cords and twines phormium or New Zealand hemp, Russian hemp, and jute are largely used. These latter varieties are also frequently employed to adulterate the stronger class of hemps. Ropes and twines of cotton are extensively made.

A rope is composed of a certain number of "strands," the strand being itself made up of many "yarns."

Ropes are designated by the method followed in their construction, as:

Hawser-laid: Three strands of yarn twisted *left*-hand, the yarn being twisted *right*-hand.

Cable-laid: Three strands of hawser-laid rope twisted *right*-hand.

Shroud-laid or *four-strand* consists of a central strand or core with four strands twisted around it.

The twist in each successive operation is in a different direction from the preceding, and this alternation of direction serves to some extent to preserve the parallelism of the fibres.

A good hemp rope is hard but pliant, yellowish or greenish gray in color, with a certain silvery or pearly lustre. A dark or blackish color indicates that the hemp suffered from fermentation in the process of curing, and brown spots show that the rope was spun while the fibres were damp, and is consequently weak and soft in those places. Sometimes a rope is made with inferior hemp on the inside, covered with yarn of good material. This may be detected by dissecting a portion of the rope. Other inferior ropes are made from short fibres, or with strands of unequal length or unevenly spun, the rope in the first place appearing woolly, on account of ends of fibres projecting, and in the latter case the irregularity of manufacture is evident on inspection.

A test for ascertaining the purity of Manila hemp rope consists in forming balls of loose fibre of the ropes to be tested and burning them completely to ashes: pure Manila burns to a dull grayish-black ash; sisal leaves a whitish-gray ash; combinations

of Manilla and sisal yield a mixed ash resembling the beard of a man turning from black to gray. Manila hemp is frequently adulterated with phormium (New Zealand flax) and Russian hemp, both of which are much inferior in strength.

To compute the strain that can be borne with safety by new ropes, hawsers, and cables square the circumference of the rope, etc., and multiply it by the coefficient given in Table 23.

Table 23.

COEFFICIENTS FOR COMPUTING THE SAFE STRAIN THAT MAY BE BORNE BY ROPES, HAWSERS, AND CABLES.

Description.	Ropes.				Hawsers.		Cables.	
	White.		Tarred.		White	Tar'd	White	Tar'd
	3 Strands.	4 Strands.	3 Strands.	4 Strands.	3 Strands.	3 Strands.	3 Strands.	Strands.
Circumference in ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs
White rope, 2.5 to 6 ins.	1140	1330	....	....	600	....	....	....
White rope, 6 to 8 ins.	1090	1260	....	....	570	....	510	....
White rope, 8 to 12 ins.	1045	880	....	....	530	....	530	....
White rope, 12 to 18 ins.	....	....	....	....	550	....	550	....
White rope, 18 to 26 ins.	....	....	....	....	....	....	560	....
Tarred rope, 2.5 to 5 ins.	....	....	855	1005	....	460	....	....
Tarred rope, 5 to 8 ins.	....	....	825	940	....	480	....	....
Tarred rope, 8 to 12 ins.	....	....	780	820	....	505	....	505
Tarred rope, 12 to 18 ins.	....	....	....	....	....	....	....	525
Tarred rope, 18 to 26 ins.	....	....	....	....	....	...	....	550
Manila rope, 2.5 to 6 ins.	810	950	....	....	440	....	....	....
Manila rope, 6 to 12 ins.	760	835	....	...	465	....	510	....
Manila rope, 12 to 18 ins.	....	....	....	....	....	....	535	....
Manila rope, 18 to 26 ins.	....	....	....	....	....	...	560	....

When it is required to ascertain the weight or strain that can be borne by ropes, etc., in general use, the above units should be reduced *one third,* in order to meet the reduction of their strength by chafing and exposure to the weather.

TABLE 24.
STRENGTH OF MANILA ROPE.

Diam. Ins.	Circ. Ins.	Wt. per Foot. Lbs.	Breaking Load.		Diam. Ins.	Circ. Ins.	Wt. per Foot. Lbs.	Breaking Load.	
			Tons.	Lbs.				Tons.	Lbs.
.239	¾	.019	.25	560	1.91	6	1.19	11.4	25536
.318	1	.033	.35	784	2.07	6½	1.39	13.0	29120
.477	1½	.074	.70	1568	2.23	7	1.62	14.6	32704
.636	2	.132	1.21	2733	2.39	7½	1.86	16.2	36288
.795	2½	.206	1.91	4278	2.55	8	2.11	17.8	39872
.955	3	.297	2.73	6115	2.86	9	2.67	21.0	47040
1.11	3½	.404	3.81	8534	3.18	10	3.30	24.2	54208
1.27	4	.528	5.16	11558	3.50	11	3.99	27.4	61376
1.43	4½	.668	6.60	14784	3.82	12	4.75	30.6	68544
1.59	5	.825	8.20	18368	4 14	13	5.58	33.8	75712
1.75	5½	.998	9.80	21952	4.45	14	6.47	37.0	82880

The strength of Manila ropes is very variable. The above table supposes an average quality. Ropes of good *Italian* hemp are considerably stronger than Manila ; but their cost excludes them from general use. The tarring of ropes is said to lessen their strength ; and, when exposed to the weather, their durability also. The use of it in standing rigging is partly to diminish contraction and expansion by alternate wet and dry weather.

The strengths of pieces from the same coil may vary 25 per cent.

A few months of exposed work weakens ropes 20 to 50 per cent.

Wire.

A rod, thread, or filament of various metals of uniform section, usually cylindrical; but various forms, such as oval, half round, square, and triangular, are also made.

The sizes of wires are estimated by certain more or less recognized standard wire gauges. The most commonly quoted is the Birmingham wire gauge. It gives forty measurements, which bear no definite relation to each other, ranging from the largest, No. 0000 = .454 inch, to No. 36 = .004 inch. The Brown & Sharpe gauge is also extensively recognized. In it the gradations are uniform, increasing in geometric ratio, so that the size of each successive number is found by multiplying the preceding by 1.123. The standard is calculated from wire No. 36, which represents a diameter of .005 inch.

The following table gives the dimensions of each size of several of the gauges in ordinary use:

TABLE 25.
WIRE AND SHEET-METAL GAUGES COMPARED.

Number of Gauge.	Birmingham Wire Gauge.	American or Brown & Sharpe Gauge.	Roebling's and Washburn & Moen's Gauge.	Trenton Iron Co.'s Wire Gauge.	British Imperial Standard Wire Gauge. Legal Standard in Great Britain since March 1, 1884		U. S. Standard Gauge for Sheet and Plate Iron and Steel. Legal Standard since July 1, 1893.	Number of Gauge.
	Inch.	Inch.	Inch.	Inch.	Inch.	Millim.	Inch.	
0000000	....	......	.49	....	.5	12.7	.5	7/0
000000	......	......	.46	....	.464	11.78	.469	6/0
00000	....	......	.43	.45	.432	10.97	.438	5/0
0000	.454	.46	.393	.40	.4	10.16	.406	4/0
000	.425	.40964	.362	.36	.372	9.45	.375	3/0
00	.38	.3648	.331	.33	.348	8.84	.344	2/0
0	.34	.32486	.307	.305	.324	8.23	.313	0
1	.3	.2893	.283	.285	.3	7.62	.281	1
2	.284	.25763	.263	.265	.276	7.01	.266	2
3	.259	.22942	.244	.245	.252	6.4	.25	3
4	.238	.20431	.225	.225	.232	5.89	.234	4
5	.22	.18194	.207	.205	.212	5.38	.219	5
6	.203	.16202	.192	.19	.192	4.88	.203	6
7	.18	.14428	.177	.175	.176	4.47	.183	7
8	.165	.12849	.162	.16	.16	4.06	.172	8
9	.148	.11443	.148	.145	.144	3.66	.156	9
10	.134	.10189	.135	.13	.128	3.26	.141	10
11	.12	.09074	.12	.1175	.116	2.95	.125	11
12	.109	.08081	.105	.105	.104	2.64	.109	12
13	.095	.07196	.092	.0925	.092	2.34	.094	13
14	.083	.06408	.08	.08	.08	2.03	.078	14
15	.072	.05707	.072	.07	.072	1.83	.07	15
16	.065	.05082	.063	.061	.064	1.63	.0625	16
17	.058	.04526	.054	.0525	.056	1.42	.0563	17
18	.049	.0403	.047	.045	.048	1.22	.05	18
19	.042	.03589	.041	.04	.04	1.01	.0438	19
20	.035	.03196	.035	.035	.036	.91	.0375	20
21	.032	.02846	.032	.031	.032	.81	.0344	21
22	.028	.02535	.028	.028	.028	.71	.0313	22
23	.025	.02257	.025	.025	.024	.61	.0281	23
24	.022	.0201	.023	.0225	.022	.56	.025	24
25	.02	.0179	.02	.02	.02	.51	.0219	25
26	.018	.01594	.018	.018	.018	.45	.0188	26
27	.016	.01419	.017	.017	.0164	.42	.0172	27
28	.014	.01264	.016	.016	.0148	.38	.0156	28
29	.013	.01126	.015	.015	.0136	.35	.0141	29
30	.012	.01002	.014	.014	.0124	.31	.0125	30
31	.01	.00893	.0135	.013	.0116	.29	.0109	31
32	.009	.00795	.013	.012	.0108	.27	.0101	32
33	.008	.00708	.011	.011	.01	.25	.0094	33
34	.007	.0063	.01	.01	.0092	.23	.0086	34
35	.005	.00561	.0095	.0095	.0084	.21	.0078	35
36	.004	.005	.009	.009	.0076	.19	.007	36
37	....	.00445	.0085	.0085	.0068	.17	.0066	37
38	....	.00396	.008	.008	.006	.15	.0063	38
39	....	.00353	.0075	.0075	.0052	.13	.....	39
40	....	.00314	.007	.007	.0048	.12	....	40
41	....	......	....	....	.0044	.11	.....	41
42	....	......	....	....	.004	.10	.....	42
43	....	......	....	....	.0036	.09	.....	43
44	....	......	....	....	.0032	.08	.....	44
45	....	......	....	....	.0028	.07	.....	45
46	....	......	....	....	.0024	.06	.....	46
47	....	......	....	....	.002	.05	.....	47
48	....	......	....	....	.0016	.04	.....	48
49	....	......	....	....	.0012	.03	.....	49
50	...	......	....	...	.001	.025	.....	50

TABLE 26.

U. S. STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL, 1893.

Number of Gauge.	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Approximate Thickness in Millimetres.	Weight per Square Foot in Ounces Avoirdupois.	Weight per Square Foot in Pounds Avoirdupois.	Weight per Square Foot in Kilograms.	Weight per Square Metre in Kilograms.	Weight per Square Metre in Pounds Avoirdupois.
0000000	1/2	0.5	12.7	320	20.	9.072	97.65	215.28
000000	15/32	0.46875	11.90625	300	18.75	8.505	91.55	201.82
00000	7/16	0.4375	11.1125	280	17.5	7.938	85.44	188.37
0000	13/32	0.40625	10.31875	260	16.25	7.371	79.33	174.91
000	3/8	0.375	9.525	240	15.	6.804	73.24	161.46
00	11/32	0.34375	8.73125	220	13.75	6.237	67.13	148.00
0	5/16	0.3125	7.9375	200	12.5	5.67	61.03	134.55
1	9/32	0.28125	7.14375	180	11.25	5.103	54.93	121.09
2	17/64	0.265625	6.746875	170	10.625	4.819	51.88	114.37
3	1/4	0.25	6.35	160	10.	4.536	48.82	107.64
4	15/64	0.234375	5.953125	150	9.375	4.252	45.77	100.91
5	7/32	0.21875	5.55625	140	8.75	3.969	42.72	94.18
6	13/64	0.203125	5.159375	130	8.125	3.685	39.67	87.45
7	3/16	0.1875	4.7625	120	7.5	3.402	36.62	80.72
8	11/64	0.171875	4.365625	110	6.875	3.118	33.57	74.00
9	5/32	0.15625	3.96875	100	6.25	2.835	30.52	67.27
10	9/64	0.140625	3.571875	90	5.625	2.552	27.46	60.55
11	1/8	0.125	3.175	80	5.	2.268	24.41	53.82
12	7/64	0.109375	2.778125	70	4.375	1.984	21.36	47.09
13	3/32	0.09375	2.38125	60	3.75	1.701	18.31	40.36
14	5/64	0.078125	1.984375	50	3.125	1.417	15.26	33.64
15	9/128	0.0703125	1.7859375	45	2.8125	1.276	13.73	30.27
16	1/16	0.0625	1.5875	40	2.5	1.134	12.21	26.91
17	9/160	0.05625	1.42875	36	2.25	1.021	10.99	24.22
18	1/20	0.05	1.27	32	2.	0.9072	9.765	21.53
19	7/160	0.04375	1.11125	28	1.75	0.7938	8.544	18.84
20	3/80	0.0375	0.9525	24	1.5	0.6804	7.324	16.15
21	11/320	0.034375	0.873125	22	1.375	0.6237	6.713	14.80
22	1/32	0.03125	0.793750	20	1.25	0.567	6.103	13.46
23	9/320	0.028125	0.714375	18	1.125	0.5103	5.493	12.11
24	1/40	0.025	0.635	16	1.	0.4536	4.882	10.76
25	7/320	0.021875	0.555625	14	0.875	0.3969	4.272	9.42
26	3/160	0.01875	0.47625	12	0.75	0.3402	3.662	8.07
27	11/640	0.0171875	0.4365625	11	0.6875	0.3119	3.357	7.40
28	1/64	0.015625	0.396875	10	0.625	0.2835	3.052	6.73
29	9/640	0.0140625	0.3571875	9	0.5625	0.2551	2.746	6.05
30	1/80	0.0125	0.3175	8	0.5	0.2268	2.441	5.38
31	7/640	0.0109375	0.2778125	7	0.4375	0.1984	2.136	4.71
32	13/1280	0.01015625	0.25796875	6½	0.40625	0.1843	1.983	4.37
33	3/320	0.009375	0.238125	6	0.375	0.1701	1.831	4.04
34	11/1280	0.00859375	0.21828125	5½	0.34375	0.1559	1.678	3.70
35	5/640	0.0078125	0.1984375	5	0.3125	0.1417	1.526	3.36
36	9/1280	0.00703125	0.17859375	4½	0.28125	0.1276	1.373	3.03
37	17/2560	0.006640625	0.168671875	4¼	0.265625	0.1205	1.297	2.87
38	1/160	0.00625	0.15875	4	0.25	0.1134	1.221	2.69

Table 27.

WIRE: IRON, STEEL, AND COPPER.

WEIGHT OF ONE FOOT IN LENGTH.

Diameters by the Birmingham Gauge for Iron Wire, Sheet Iron, and Steel.					Diameter by Brown & Sharpe's Gauge.				
No. of Gauge.	Diameter.	Iron.	Steel.	Copper.	No. of Gauge.	Diameter.	Iron.	Steel.	Copper.
	In.	Pound.	Pound.	Pound.		In.	Pound.	Pound.	Pound.
0000	.454	.546207	.551860	.623918	0000	.46000	.56074	.566030	.640513
000	.425	.478656	.483172	.546752	000	.40964	.444683	.448879	.507946
00	.380	.382660	.386270	.437099	00	.36480	.352659	.355986	.402830
0	.340	.306340	.309280	.349921	0	.32486	.279665	.282303	.319451
1	.300	.238500	.240750	.272430	1	.28930	.221786	.223891	.253342
2	.284	.218738	.315755	.244146	2	.25763	.175888	.177548	.200911
3	.259	.177765	.179442	.203054	3	.22942	.139480	.140796	.159323
4	.238	.150107	.151523	.171461	4	.20431	.110616	.111660	.126353
5	.220	.128260	.129470	.146507	5	.18194	.087720	.088548	.100200
6	.203	.109204	.110234	.124740	6	.16202	.069565	.070221	.079462
7	.180	.085860	.086667	.098075	7	.14428	.055165	.055685	.063013
8	.165	.072146	.072827	.082410	8	.12849	.043751	.044164	.049976
9	.148	.058046	.058593	.066303	9	.11443	.034699	.035026	.039636
10	.134	.047583	.048032	.054353	10	.10189	.027512	.027772	.031426
11	.120	.038160	038520	.043589	11	.090742	.021820	.022026	.024924
12	.109	.031485	.031782	.035964	12	.080808	.017304	.017468	.019766
13	.095	.028016	.024142	.027319	13	.071961	.013722	.013851	.015674
14	.083	.018256	.018428	020858	14	064084	.010886	.010989	.012435
15	.072	.013738	.013867	.015693	15	.057068	.008631	.008712	.009859
16	.065	.011196	.011302	.012789	16	.050820	.006845	.006909	.007819
17	.058	.008915	.008999	.010183	17	.045257	.005427	.005478	.006199
18	.049	.006833	.006423	.007268	18	.040303	.004304	.004344	.004916
19	.042	.004675	.004719	.005340	19	.035890	.003413	.003445	.003899
20	.035	.003246	.003277	.003708	20	.031961	.002708	.002734	.003094
21	.032	.002714	.002739	.003100	21	.028462	.002147	.002167	.002452
22	.028	.002078	.002097	.002373	22	.025347	.001703	.001719	.001945
23	.025	.001656	.001672	.001892	23	.022571	.001350	.001363	.001542
24	.022	.001283	.001295	001465	24	.020100	.001071	.001081	.001223
25	.020	.001060	.001070	.001211	25	.017900	.0008491	.0008571	.0009699
26	.018	.0008586	.0008687	.0009807	26	.015940	.0006734	.0006797	.0007692
27	.016	.0006784	0006848	.0007749	27	.014195	.0005340	.0005391	.0006099
28	.014	.0005194	.0005243	.0005933	28	012641	.0004235	.0004275	.0004837
29	.013	.0004479	.0004521	.0005116	29	.011257	.0003358	.0003389	.0003835
30	.012	0003816	.0003852	.0004359	30	.010025	.0002663	.0002688	.0003042
31	.010	.0002650	.0002675	.0003027	31	.008928	.0002113	.0002132	.0002413
32	.009	.0002147	.0002167	.0002452	32	.007950	.0001675	.0001691	.0001913
33	.008	.0001696	.0001712	.0001937	33	.007080	.0001328	.0001341	.0001517
34	.007	.0001299	.0001311	.0001483	34	.006304	.0001053	.0001063	.0001204
35	.005	.00006625	.00006688	.00007568	35	.005614	.00008366	.00008445	.0000956
36	.004	.0000424	.0000428	.00004843	36	.005000	.00006625	.00006687	.0000757
Sp. grav..		7.77	7.85	8.89	37	.004453	.00005255	.00005304	.00006003
Wts. of a					38	.003965	.00004166	.00004205	.00004758
Cubic ft...		485.	490.	555.	39	.003531	.00003305	.00003336	.00003775
Cubic in...		.2807	.2836	.3212	40	.003144	.00002620	.00002644	.00002992

Table 28.

SIZE AND WEIGHT OF IRON AND STEEL WIRE.

Number by Wire Gauge.	Diameter in Decimals of 1 Inch.	Feet to the Pound.	Weight of 1 Foot in Decimals of 1 Pound.	Weight of 1 Mile in Pounds.	Length of 1 Bundle (63 lbs.) in Yards.	Area of Section in Decimals of 1 Square Inch.	Actual Breaking Weight of Bright Market Wire in Pounds.	Tensile Strength of Bright Market Wire per Square Inch of Section in Pounds.
00000	.450	1.863	.5366	2833.248	39.12	.15904	12598	78903
0000	.400	2.358	.4240	2238.878	49.52	.12566	9955	79326
000	.360	2.911	.3435	1813.574	61.13	.10179	8124	79813
00	.330	3.465	.2886	1523.861	72.77	.08553	6480	80437
0	.305	4.057	.2465	1301.678	85.20	.07306	5926	81110
1	.285	4.645	.2153	1136.678	97.55	.06379	5226	81925
2	.265	5.374	.1861	982.555	112.85	.05515	4570	82873
3	.245	6.286	.1591	839.942	132.01	.04714	3948	83756
4	.225	7.454	.1342	708.365	156.53	.03976	3374	84862
5	.205	8.976	.1114	588.139	188.50	.03301	2839	86000
6	.190	10.453	.09566	505.084	219.51	.02835	2476	87349
7	.175	12.322	.08115	428.472	258.76	.02405	2136	88802
8	.160	14.736	.06786	358.3008	309.46	.02011	1813	90153
9	.145	17.950	.05571	294.1488	376.95	.01651	1507	91276
10	.130	22.333	.04477	236.4384	468.99	.01327	1233	92890
11	.1175	27.340	.03658	193.1424	574.14	.01084	1010	93194
12	.105	34.219	.02922	154.2816	718.60	.00866	810	93530
13	.0925	44.092	.02268	119.7504	925.93	.00672	631	93917
14	.080	58.916	.01697	89.6016	1237.24	.00503	474	94299
15	.070	76.984	.01299	68.5872	1616.66	.00385	372	96703
16	.061	101.488	.00985	52.008	2131.25	.00292	292	99922
17	.0525	137.174	.00729	38.4912	2880.65	.00216	222	102740
18	.045	186.335	.00537	28.3378	3913.04	00159	169	106343
19	.040	235.084	......	22.3872	4936.76	.0012566	137	109362
20	.035	308.079	......	17.1389	6469.66	.0009621	107	111184
21	.031	392.772	......	13.4429	......	.0007547	.....	....
22	.028	481.281	......	10.9718	......	.0006157	.....	....
23	.025	603.863	......	8.7437	......	.0004909	.....	....
24	.0225	745.710	......	7.0805	......	.0003976	.....	....
25	.020	943.396	......	5.5968	......	.0003142	.....	....
26	.018	1164.689	......	4.5334	......	.0002545	.....	....
27	.017	1305.670	......	4.0439	......	.0002270	.....	....
28	.016	1476.869	......	3.5819	......	.0002011	.....	....
29	.015	1676.989	......	3.1485	......	.0001767	.....	....
30	.014	1925.321	......	2.7424	......	.0001539	.....	....
31	.013	2232.653	......	2.3649	......	.0001327	.....	....
32	.012	2620.607	......	2.0148	......	.0001131	.....	....
33	.011	3119.092	......	1.6928	......	.0000950	.....	....
34	.010	3773.584	......	1.3992	......	.00007854	.....	....
35	.0095	4182.508	......	1.2624	......	.00007088	.....	....
36	.009	4657.728	......	1.1836	......	.00006362	.....	....
37	.0085	5222.035	......	1.0111	......	.00005675	.....	....
38	.008	5896.147	......	.89549	......	.00005027	.....	....
39	.0075	6724.291	......	.78672	......	.00004418	.....	....
40	.007	7698.253	......	.68587	......	.00003848	.....	....

The strengths given in the last column of the above table are based upon tests made with bright (not annealed) charcoal-iron wire. The strength of Swedish iron is about 10 per cent less, and that of mild Bessemer and ordinary crucible cast steel about 10 and 25 per cent respectively greater, than that of charcoal-iron. Special grades of crucible cast steel vary between 30 and 100 per cent over charcoal-iron. Galvanizing reduces the tensile strength by about 10 and annealing by about 25 per cent, while tinning and coppering exert no apparent influence upon the metal.

TABLE 29.

TENSILE STRENGTH OF WIRE.

	Pounds per Square Inch.
German silver	81,735 to 92,224
Bronze	78,049
Brass (as drawn)	81,114 " 98,578
Copper " "	37,607 " 46,494
Copper (annealed)	34,936 " 45,210
Iron	59,246 " 97,908
Steel	103,272 " 318,823

TABLE 30.

NUMBER OF YARDS OF IRON WIRE TO THE BUNDLE.

(Bundle weighs 63 lbs.)

B. W. Gauge.	Yards per Bundle.	B. W. Gauge.	Yards per Bundle.
No. 0	71	No. 11	529
" 1	91	" 12	700
" 2	105	" 13	893
" 3	121	" 14	1142
" 4	143	" 15	1465
" 5	170	" 16	1954
" 6	203	" 17	2540
" 7	239	" 18	3150
" 8	286	" 19	4085
" 9	342	" 20	4912
" 10	420		

Wire Ropes.

Ordinary wire rope is composed of six strands, each containing seven or nineteen wires, laid up about a hemp or wire-strand centre, and is commonly known as "seven-wire" or "nineteen-wire rope," as the case may be.

Rope made with a hemp centre is more pliable than that which has a wire centre.

For special purposes ropes of twelve, sixteen, or other numbers of wire to the strand are made.

Hawser-ropes are made of six strands, each of which is composed of twelve wires laid about a hemp centre.

Wire ropes are made in several ways, according to the purposes for which they are to be used. *Ordinary* wire ropes are made with a long or short twist or "lay"; the component strands are laid up into rope in a direction opposite to that in which the wires are laid into strands—that is, if the wires in the strands are laid from right to left the strands are laid into rope from left to right. In the *Lang-lay* or *Universal-lay* rope the wires are laid into strands and the strands into rope in the same direction—that is, if the wire is laid in the strands from right to left the strands are also laid into rope from right to left. In *locked* wire rope the wires of the exterior strands are drawn to such a shape that each one interlocks with its neighbor in such a way as to present a smooth cylindrical surface like a solid round bar. This style of rope cannot be spliced in the ordinary way; joints are made by steel couplings of suitable form.

Wire rope should not be coiled or uncoiled like hemp rope. When it is wound upon a reel the reel should revolve on a spindle while the rope is paid off; when laid up in a coil, not on a reel, roll the coil on the ground like a wheel, and pay off the rope in that manner, so that there will be no danger of untwisting or "kinking."

To preserve wire rope laid under ground or under water it is coated with a mixture of mineral tar and fresh-slaked lime in the proportion of one bushel of lime to one barrel of tar. The mixture is boiled and the rope saturated with it while hot; sawdust is sometimes added to give the mixture body. Wire rope exposed to the weather is coated with raw linseed-oil, or with a paint composed of equal parts of Spanish brown or lampblack with linseed-oil.

TABLE 81.

STRENGTH OF IRON ROPES.

HOISTING-ROPE, 6 STRANDS OF 19 WIRES EACH.

Trade No.	Circumference in Inches.	Diameter.	Weight per Foot in Lbs. of Rope with Hemp	Breaking Strain in Tons of 2000 Lbs.	Proper Working Load in Tons of 2000 Lbs.	Circumference of Hemp Rope of Equal	Min. Size of Drum or Sheave

STANDING ROPE, 16 STRANDS OF 7 WIRES EACH.

11	4¾	1½	3.37	36	9	10¾	....
12	4¼	1⅜	2.77	30	7½	10	....
13	4	1¼	2 28	25	6¼	9½	..
14		1⅛	1 82	20	5	8	....
15		1	1.50	16	4	7	....
16		⅞	1.12	12.3	3	6½	...
17		¾	0 92	9	2¼	5½	....
18		11/16	0 70	7.6	2	5	....
19		⅝	0.57	5 8	1½	4¾	....
20		9/16	0 41	4.1	1	4	....
21		½	0 31	2 83	¾	3½	...
22		7/16	0 23	2.13	½	2⅞	
23	16	⅜	0.21	1 65	⅜	2½	....
24		5/16	0.16	1.23	¼	2¼	...
25		9/32	0.12	1 03	1/6	1	..

TABLE 82.

STRENGTH OF STEEL ROPES.

CAST STEEL HOISTING-ROPE WITH 6 STRANDS OF 19 WIRES EACH.

Trade No.	Circumference. Inches.	Diameter. Inches.	Weight per Foot in Lbs.	Breaking Strain in Tons of 2000 Lbs.	Proper Working Load in Tons of 2000 Lbs	Circumference of Hemp Rope of Equal Strength.	Min. Size of Drum or Sheave in Feet.
1	7	2¼	8.00	155	31		9
2	6¼	2	6.30	125	25		8
3	5½	1¾	5.25	106	21	15½	7½
4	5	1⅝	4.10	86	17	14½	6
5	4¾	1½	3.65	77	15	13½	6½
5½	4¼	1⅜	3.00	63	12	12¾	5½
6	4	1¼	2.50	52	10	11¾	5
7	3½	1⅛	2.00	42	8	10	4½
8	3⅛	1	1.58	33	6	9½	4
9	2¾	⅞	1.20	25	5	8	3½
10	2⅜	¾	0.88	18	3½	6½	3¼
10¼	2	⅝	0.60	14	2½	5¾	3
10½	1¾	9/16	0.48	9	1¾	4¾	2¾
10¾	1½	½	0.39	7½	1½	4½	2
10a	1⅜	7/16	0.29	6	1¼	4	1¾
10b	1¼	⅜	0.23	4¼	⅞	3½	1½
	1	5/16	0.16	3	¾	3	1¼

STANDING ROPE FOR DERRICKS, ETC., WITH 6 STRANDS OF 7 WIRES EACH.

11	[illegible]	1⅝	3.37	62	13	15	...
12	[illegible]	1½	2.77	52	11	13	...
13	[illegible]	1¼	2.28	44	9	12	...
14	[illegible]	1⅛	1.82	36	7	10¾	...
15	[illegible]	1	1.50	30	6	10	...
16	[illegible]	⅞	1.12	22	4½	8½	...
17	[illegible]	¾	0.92	17	3½	7¼	...
18	[illegible]	11/16	0.70	14	2¾	6¼	...
19	[illegible]	⅝	0.57	11	2	5¾	...
20	[illegible]	9/16	0.41	8	1¾	5	...
21	[illegible]	½	0.31	6	1¼	4¾	...
22	[illegible]	7/16	0.23	5	1	4¼	...
23	1 3/16	⅜	0.21	4	⅞	3¾	...
24	1	5/16	0.16	3	¾	3¼	...
25	⅞	9/32	0.12	2¾	⅝	2¾	...

Table 83.

STRENGTH OF GALVANIZED WIRE ROPES.

Approximate Diameter in Inches.	Circumference in Inches.	Estimated Weight per Foot. Pounds.	Breaking Strain in Tons of 2000 Pounds.	Circumference of Hemp Rope of Equal Strength in Inches.	Approximate Diameter in Inches.	Circumference in Inches.	Estimated Weight per Foot. Pounds.	Breaking Strain in Tons of 2000 Pounds.	Circumference of Hemp Rope of Equal Strength in Inches.
1.75	5½	4.43	43	11	0.80	2½	0.92	8½	5
1.67	5¼	4.08	40	10½	0.72	2¼	0.75	7	4½
1.60	5	3.67	35	10	0.64	2	0.59	6	4
1.51	4¾	3.50	33	9½	0.56	1¾	0.42	5	3½
1.43	4½	3.17	30	9	0.48	1½	0.30	3½	3
1.35	4¼	2.75	26	8½	0.40	1¼	0.21	2½	2½
1.27	4	2.38	23	8	0.36	1⅛	0.17	2¼	2¼
1.19	3¾	2.13	20	7½	0.32	1	0.14	2	2
1.11	3½	1.79	16	7	0.28	⅞	0.11	1	1½
1.04	3¼	1.58	14	6½	0.24	¾	0.085	¾	1¼
0.96	3	1.33	12	6	0.20	⅝	0.06	⅝	1
0.88	2¾	1.13	10	5½	0.16	½	0.045	⅜	¾

Table 84.

STRENGTH OF FLAT WIRE ROPES.

Size in Inches.	Approximate Weight per Foot. Pounds.	Breaking Strain (Approximate) in Pounds. Iron.	Breaking Strain (Approximate) in Pounds. Cast Steel.	Size in Inches.	Approximate Weight per Foot Pounds.	Breaking Strain (Approximate) in Pounds. Iron.	Breaking Strain (Approximate) in Pounds. Cast Steel
2 × ⅜	1.35	20000	40000	3 × ½	2.40	37500	75000
2½ × ⅜	1.70	25000	50000	3½ × ½	2.85	43750	87500
3 × ⅜	2.05	30000	60000	4 × ½	3.30	50000	100000
3½ × ⅜	2.40	35000	70000	5 × ½	4.20	62500	125000
4 × ⅜	2.75	40000	80000	6 × ½	5.10	75000	150000
5 × ⅜	3.45	50000	100000	7 × ½	6.00	87500	175000
6 × ⅜	4.15	60000	120000	8 × ½	6.90	100000	200000

For safe working load allow one fifth to one seventh of the breaking strain.

TABLE 35.

STRENGTH OF GALVANIZED STEEL CABLES.

Cables laid up like Wire Rope.			Cables composed of Wires laid Parallel and Bound Together.		
Diameter in Inches.	Weight per Foot. Pounds.	Ultimate Strength in Tons of 2000 Lbs.	Diameter in Inches.	Weight per Foot. Pounds.	Ultimate Strength in Tons of 2000 Lbs.
2⅝	11.7	220	4	35.26	760
2½	10.3	200	3¾	30.78	665
2⅜	9.2	180	3½	26.23	580
2¼	8.3	155	3	18.34	400
2	6.5	110	2¾	15.40	325
1⅞	5.8	100	2½	12.88	262
1¾	5.6	95	......	......	......
1⅝	4.3	75	......	......	......
1½	3.7	65	......	......	......

TABLE 36.

STRAIN ON HOISTING-CHAINS AND CABLES ON INCLINED PLANES.

Rise per 100 Feet Horizontal.	Angle of Inclination.	Strain in Lbs. per Ton of 2000 Lbs.	Rise per 100 Feet Horizontal.	Angle of Inclination.	Strain in Lbs. per Ton of 2000 Lbs.
5	2° 52′	112	105	46° 24′	1456
10	5 43	211	110	47 44	1488
15	8 32	308	115	49	1517
20	11 19	404	120	50 12	1545
25	14 3	497	125	51 21	1569
30	16 42	585	130	52 26	1592
35	19 18	672	135	53 29	1614
40	21 49	754	140	54 28	1635
45	24 14	832	145	55 25	1654
50	26 34	905	150	56 19	1671
55	28 49	975	155	57 11	1687
60	30 58	1039	160	58	1702
65	33 2	1100	165	58 47	1716
70	35	1157	170	59 33	1730
75	36 53	1210	175	60 16	1743
80	38 40	1259	180	60 57	1754
85	40 22	1304	185	61 37	1766
90	42	1347	190	62 15	1776
95	43 32	1387	195	62 52	1785
100	45	1422	200	63 27	1794

In calculating the strains on the chain an allowance of 12 lbs. per ton has been made for the rolling friction of the load on a level. An additional allowance should be made for the weight of the chain, depending of course on its size and length. The breaking strain of the chain should be six or seven times that which it is to bear.

Table 37.

STRENGTH OF CRANE-CHAINS.

"D. B. G." Special Crane.							Crane.		
Size of Chain. Inches.	Pitch A. Approximately. Inches.	Weight per Foot in Pounds. Approximately.	Outside Width. B. Inches.	Proof Test. Pounds.	Average Breaking Strain. Pounds.	Ordinary Safe Load. General Use. Pounds.	Proof Test. Pounds.	Average Breaking Strain. Pounds.	Ordinary Safe Load. General Use. Pounds.
1/4	25/32	7/8	7/8	1932	3864	1288	1680	3360	1120
5/16	27/32	1	1 1/16	2898	5796	1932	2520	5040	1680
3/8	31/32	1 7/10	1 1/4	4186	8372	2790	3640	7280	2427
7/16	1 5/32	2	1 3/8	5796	11592	3864	5040	10080	3360
1/2	1 11/32	2 1/2	1 11/16	7728	15456	5182	6720	13440	4480
9/16	1 15/32	3 2/10	1 7/8	9660	19320	6440	8400	16800	5600
5/8	1 23/32	4 1/8	2 1/16	11914	23828	7942	10360	20720	6907
11/16	1 27/32	5	2 1/4	14490	28980	9660	12600	25200	8400
3/4	1 31/32	5 7/8	2 1/2	17388	34776	11592	15120	30240	10080
13/16	2 3/32	6 7/10	2 11/16	20286	40572	13524	17640	35280	11760
7/8	2 7/32	8	2 7/8	22484	44968	14989	20440	40880	13627
15/16	2 15/32	9	3 1/16	25872	51744	17248	23520	47040	15680
1	2 19/32	10 7/10	3 1/4	29568	59136	19712	26880	53760	17920
1 1/16	2 23/32	11 2/10	3 5/16	33264	66538	22176	30240	60480	20160
1 1/8	2 27/32	12 1/2	3 3/4	37576	75152	25050	34160	68320	22773
1 3/16	3 5/32	13 7/10	3 7/8	41888	83776	27925	38080	76160	25387
1 1/4	3 7/32	16	4 1/8	46200	92400	30800	42000	84000	28000
1 5/16	3 15/32	16 1/2	4 3/8	50512	101024	33674	45920	91840	30613
1 3/8	3 5/8	18 4/10	4 9/16	55748	111496	37165	50680	101360	33787
1 7/16	3 25/32	19 7/10	4 3/4	60368	120736	40245	54880	109760	36587
1 1/2	3 31/32	21 7/10	5	66528	133056	44352	60480	120960	40320

The distance from centre of one link to centre of next is equal to the inside length of link, but in practice 1/32 inch is allowed for weld. This is approximate, and where exactness is required chain should be made so.

For Chain sheaves.—The diameter, if possible, should be not less than twenty times the diameter of chain used. *Example:* For 1-inch chain use 20-inch sheaves.

VIII. FASTENINGS.

Nails.

There is a large variety of nails, named chiefly from the shape of their heads or points, or according to the particular use for which they are intended.

In former times nails were described according to their price per 100; thus "tenpenny nails" and "fourpenny nails" were those costing tenpence and fourpence per 100 respectively. These terms are still used, but their meaning is indefinite or has reference to nails of a particular length.

CAST NAILS, made by running iron into moulds, are brittle and inferior in strength.

WROUGHT NAILS are forged either by hand labor or machine power. They are frequently designated by the names *clasp* or *clench* nails, on account of their property of bearing bending without breaking.

CUT NAILS are made by machinery, of various thicknesses and in lengths from $\frac{3}{4}$ to 6 inches.

WIRE NAILS are made by machinery. They are round or square in section and are smooth or barbed. They are made in lengths from $\frac{5}{8}$ to 6 inches, and of different thickness, varying from Nos. 5 to 18 B. W. G.

COPPER NAILS are made of the same shape as iron nails, and are used in positions where the latter would be subject to corrosion.

COMPOSITION NAILS are made of different alloys to avoid corrosion, or to prevent galvanic action set up by iron when in contact with zinc or other metals. They are varied in shape according to the purpose for which they are to be used.

HOLDING POWER OF NAILS.—In holding power cut nails are superior to wire nails.

The main advantage of a wire nail is in its possessing a sharp point and in being easily driven.

If cut nails were pointed their efficiency in direct tension would

be increased by about 30%; wire nails without points have but half of their ordinary holding power.

The tenacity of wire nails decreases with time, but not so fast, probably, when exposed to the weather.

The nail's surface should be very slightly rough, though not granular; should not be galvanized or otherwise made smooth; and should not be barbed, and especially the barbs should not be sharp and angular. Barbing decreases the efficiency of cut nails about 32%.

Nails to be used in tension should be about three times the thickness of the thinnest piece nailed in length, and when used in shear about twice the same.

The relative holding power of nails in the common woods is about as follows: white pine 1; yellow pine 1.5; white oak 3; chestnut 1.6; beech 3.2; sycamore 2; elm 2; basswood 1.2; laurel 2.8.

Nails usually hold about 50% more when driven perpendicular to the grain than when driven along the grain.

When subject to impact nails hold less than $\frac{1}{15}$ the strain they can stand when weight is gradually applied.

TABLE 38.

WROUGHT-IRON OR CLINCH NAILS.

LENGTH AND NUMBER TO THE POUND.

Title.	Length.	Number per Pound.	Title.	Length.	Number per Pound.
6d.	2 in.	95	12d.	3¼ in.	42
7d.	2¼ "	74	16d.	3½ "	38
8d.	2½ "	62	20d.	4 "	33
9d.	2¾ "	53	30d.	4½ "	20
10d.	3 "	46			

TABLE 39.
CUT NAILS.
LENGTH AND NUMBER TO THE POUND.

ORDINARY.

Size.	Length, in inches.	No. to pound.
2d	7/8	716
3d fine	1 1/16	588
3d	1 1/16	448
4d	1 3/8	336
5d	1 3/4	216
6d	2	166
7d	2 1/4	118
8d	2 1/2	94
10d	2 3/4	72
12d	3 1/8	50
20d	3 3/4	32
30d	4 1/4	20
40d	4 3/4	17
50d	5	14
60d	5 1/2	10

LIGHT.

Size.	Length, in inches.	No. to pound.
4d	1 3/8	373
5d	1 3/4	272
6d	2	196

BRADS.

Size.	Length, in inches.	No. to pound.
6d	2	163
8d	2 1/2	96
10d	2 3/4	74
12d	3 1/8	50

CLINCH.

Length, in inches.	No. to pound.
2	152
2 1/4	133
2 1/2	92
2 3/4	72
3	60
3 1/4	43

FENCE.

Length, in inches.	No. to pound.
2	96
2 1/4	66
2 1/2	56
2 3/4	50
3	40

SPIKES.

Length, in inches.	No. to pound.
3 1/2	19
4	15
4 1/2	13
5	10
5 1/2	9
6	7

BOAT.

Length, in inches.	No. to pound.
1 1/2	206

FINISHING.

Size.	Length, in inches.	No. to pound.
4d	1 3/4	384
5d	1 3/8	256
6d	2	204
8d	2 1/2	102
10d	3	80
12d	3 5/8	65
20d	3 7/8	46

CORE.

Size.	Length, in inches.	No. to pound.
6d	2	143
8d	2 1/2	68
10d	2 1/3	60
12d	3 1/8	42
20d	3 3/4	25
30d	4 1/4	18
40d	4 3/4	14
W H	2 1/2	69
W H L	2 1/4	72

SLATE.

Size.	Length, in inches.	No. to pound.
3d	1 5/16	288
4d	1 7/16	244
5d	1 3/4	187
6d	2	146

TABLE 40.
TACKS.
SIZE AND NUMBER PER POUND.

Size.	Length.	Number to pound.	Size.	Length.	Number to pound.	Size.	Length.	Number to pound.
1 oz.	1/8	16000	4 oz.	7/16	4000	14 oz.	13/16	1143
1 1/2 "	3/16	10066	6 "	9/16	2666	16 "	7/8	1000
2 "	1/4	8000	8 "	5/8	2000	18 "	15/16	888
2 1/2 "	5/16	6400	10 "	11/16	1600	20 "	1	800
3 "	3/8	5333	12 "	3/4	1333	22 "	1 1/16	727

TABLE 41.

WIRE NAILS.

LENGTH AND NUMBER TO THE POUND.

Title.	Length. Inches.	Common Nails and Brads.	Barbed, Common.	Clinch.	Fence.	Smooth and Barbed	Fine.	Casing and Smooth and Barbed Finishing.	Flooring-brads.	Slating.	Barbed Roofing.	Shingle.
....	¾	....	....	....	....	....	....	....	....	..	714	....
.	⅞	....	....	....	....	....	....	...	....	..	469	....
2d.	1	1200	876	710	....	1558	1550	1350	....	411	411	....
3d.	1⅛	..	...	....	....	...	1140	....	....			....
3d.	1¼	720	568	429	....	980	...	913	....	25	251	....
4d.	1½	432	357	274	....	760	760	584	....	20	165	....
5d.	1¾	300	285	235	142	575	....	410	....	14	142	270
6d.	2	252	204	157	124	350	....	310	157	...	108	204
7d.	2¼	186	139	139	92	275	....	238	139	18[illegible]	...	...
8d.	2½	132	99	99	82	190	....	170	99	125	....	....
9d.	2¾	105	90	90	62	173	....	150	90	114	...	....
10d.	3	87	69	83	50	137	....	121	67	83	..	....
12d.	3¼	66	53	64	38	98	....	97	53	....	....	....
16d.	3½	51	43	59	30	81	....	72	43	....	....	....
20d.	4	35	31	43	23	71	....	54	....	....	....	....
30d.	4½	27	24	....	....	....	....	46	....	....	..	....
40d.	5	21	18	....	....	....	....	36	....	...	....	...
50d.	5½	15	....	...	....	....	....	....	....	....	.	....
60d.	6	12	....	...	...	....	....	..	....	....	..	....

TABLE 42.

WROUGHT SPIKES.

SIZE AND NUMBER IN KEG OF 150 POUNDS.

Length	1/4 In.	5/16 In.	3/8 In.	7/16 In.	1/2 In.
3 in.	2250	....	....	....	....
3½ "	1890	1208	....	....	....
4 "	1650	1135	....	....	....
4½ "	1464	1064	....	....	....
5 "	1380	930	742	....	....
6 "	1292	868	570	....	....
7 "	1161	662	482	445	306
8 "	....	635	455	384	256
9 "	....	573	424	300	240
10 "	....	....	391	270	222
11 "	....	....	....	249	203
12 "	....	....	....	236	180

TABLE 43.

WIRE SPIKES.

SIZE AND NUMBER TO THE POUND.

Title.	No. of Wire.	Length.	No. per Pound.
10d.	7	3 in.	50
16d.	6	3½ "	35
20d.	5	4 "	26
30d.	4	4½ "	20
40d.	3	5 "	15
50d.	2	5½ "	12
60d.	1	6 "	10
6½ in.	1	6½ "	9
7 "	0	7 "	7
8 "	00	8 "	5
9 "	00	9 "	4½

TABLE 44.

TRACK-SPIKES.

SIZE AND NUMBER PER KEG.

Rails Used.	Spikes. Inches.	Number in Keg, 200 Pounds.	Kegs per Mile. Ties 24 Inches between Centres.
45 to 85 lbs.	$5\frac{1}{2} \times \frac{9}{16}$	380	30
40 " 52 "	$5 \times \frac{9}{16}$	400	27
35 " 40 "	$5 \times \frac{1}{2}$	490	22
24 " 35 "	$4\frac{1}{2} \times \frac{1}{2}$	550	20
24 " 35 "	$4\frac{1}{2} \times \frac{7}{16}$	725	15
18 " 24 "	$4 \times \frac{7}{16}$	820	13
16 " 20 "	$3\frac{1}{2} \times \frac{3}{8}$	1250	9
14 " 16 "	$3 \times \frac{3}{8}$	1350	8
8 " 12 "	$2\frac{1}{2} \times \frac{3}{8}$	1550	7
8 " 10 "	$2\frac{1}{2} \times \frac{5}{16}$	2200	5

TABLE 45.

STREET-RAILWAY SPIKES.

SIZE AND NUMBER PER KEG.

Spikes. Inches.	Number in Keg, 200 Pounds.	Kegs per Mile. Ties 24 In between Centres.
$5\frac{1}{2} \times \frac{9}{16}$	400	30
$5 \times \frac{1}{2}$	575	19
$4\frac{1}{2} \times \frac{7}{16}$	800	13

Screws.

Screws for screwing into wood are made of metal with sharp or bevelled threads. The points are generally made sharp, so that they may penetrate the wood; the body of the screw is tapered, so that the deeper it is driven the more tightly it will fill the hole; the thread does not extend throughout the length of the screw, but a considerable portion below the head is left smooth.

Screws are made in various lengths and diameters. They are classified according to the shape of their heads, and in some cases according to their use. The principal forms of the heads are the flat and the button or round head. The former are used when the thickness of the material is sufficient to permit the head of the screw being countersunk; the latter are used where the material is too thin to admit of countersinking, and also for ornamental purposes.

Screws to be used in damp places should be of brass.

TABLE 46.

DIMENSIONS OF WOOD SCREWS.

No.	Threads per Inch.	Diameter of Body.	Diameter of Flat Head.	Diameter of Round Head.	Diameter of Filister Head.	Lengths. Inches.	
						From	To
2	56	.0842	.1631	.1544	.1332	3/16	½
3	48	.0973	.1894	.1786	.1545	3/16	⅝
4	32, 36, 40	.1105	.2158	.2028	.1747	3/16	¾
5	32, 36, 40	.1236	.2421	.2270	.1985	3/16	⅞
6	30, 32	.1368	.2684	.2512	.2175	3/16	1
7	30, 32	.1500	.2947	.2754	.2392	¼	1⅛
8	30, 32	.1631	.3210	.2936	.2610	¼	1¼
9	24, 30, 32	.1763	.3474	.3238	.2805	¼	1⅜
10	24, 30, 32	.1894	.3737	.3480	.3035	¼	1½
12	20, 24	.2158	.4263	.3922	.3445	⅜	1¾
14	20, 24	.2421	.4790	.4364	.3885	⅜	2
16	16, 18, 20	.2684	.5316	.4866	.4300	⅜	2¼
18	16, 18	.2947	.5842	.5248	.4710	½	2½
20	16, 18	.3210	.6368	.5690	.5200	½	2¾
22	16, 18	.3474	.6894	.6106	.5557	½	3
24	14, 16	.3737	.7420	.6522	.6005	½	3
26	14, 16	.4000	.7420	.6938	.6525	¾	3
28	14, 16	.4263	.7946	.7354	.6920	⅞	3
30	14, 16	.4520	.8473	.7770	.7240	1	3

Lengths vary by 16ths from 3/16 to ½; by 8ths, from ½ to 1½; by 4ths, from 1½ to 3.

LAG- OR COACH-SCREWS are large heavy screws used where great strength is required in heavy woodwork, and for fixing iron-work to timber. They have square heads, so that they can be screwed home with a wrench.

TABLE 47.

SIZE AND WEIGHT OF LAG-SCREWS.

(The figures represent pounds per hundred.)

Length. Inches.	Diameter. Inches.				
	3/8	7/16	1/2	5/8	3/4
1½	6.88	....	....	....	....
1¾	7.50	11.75	16.88	....	....
2	8.25	12.62	17.18	....	....
2¼	9.25	12.88	18.07	....	....
2½	9.62	13.28	19.18	....	....
3	10.82	16.62	22.00	34.07	....
3½	11.50	18.18	24.00	35.88	....
4	13.31	18.88	26.82	39.25	64.00
4½	14.82	19.50	28.25	42.62	67.88
5	16.50	21.25	30.37	47.75	71.37
5½	17.37	23.56	33.88	51.62	79.37
6	18.82	25.31	35.37	55.12	86.62
7	....	....	38.94	61.88	92.75
8	....	....	44.37	68.75	97.50
9	....	....	....	77.00	108.75
10	....	....	....	90.00	124.75

TABLE 48.

HOLDING POWER OF LAG-SCREWS.

(Diameter of holes equal to diameter of the screw at the base of the thread; depth of holes 1 inch less than the screw is to be sunk.)

Wood.	Diameter. Inches.								
	1	7/8	3/4	5/8	1/2	7/16	3/8	5/16	1/4
Hemlock........	5150	4730	5090	4840	3130	2660	2100	1790	650
Oak	9270	9040	8350	7410	4300	4030	3120	2400	1400
Pine, white.......	5410	4710	4380	4350	4670	3900	2020	2110	650
" Georgia.....	7050	6240	6860	6410	4560	4060	3410	2470	1150
" Norway.....	7760	6740	6690	5980	3730	3240	2930	2250	1000

Screws for Metal are made in different forms from wood screws. The diameter of the screw is the same throughout. The threads are close together and V-shaped.

The great difference between screws for metal and those for wood is that the latter, by the pressure of their threads against the fibres, make a hole into which they will fit exactly, whereas in metal the hole has to be tapped of the exact size to receive the screw.

Unless the internal thread of the nut or of the metal into which the screw is to be driven exactly fits the thread of the screw one or the other will become distorted in screwing, they will bear unequally upon one another, and great loss of strength will ensue, together with difficulties in working.

Pins—Wedges.

PINS are round pieces of iron or wood passed through the framing of a joint in timbers to prevent them from separating, or through a tenon to keep it from drawing out of the mortice.

TRENAILS are pieces of hard wood used, like iron nails, for fastening boards to beams, for forming strong joints, etc., and occasionally, like pins, merely to secure joints formed in some other way. They are useful in positions where iron nails would rust and injure the work, and where copper nails would be too expensive.

They are made of different diameters and lengths according to the dimensions of the pieces they unite, and slightly tapering in form to facilitate driving.

WEDGES AND KEYS are made of hard wood inserted in a joint or between the sides of a tenon and the sides of a mortice. They are used for tightening up joints or forcing parts into position before inserting bolts, etc. They should be dipped in white lead before using.

Bolts and Nuts.

Bolts are manufactured either "rough" or "finished." The finished bolt is the rough bolt turned to exact dimensions. Rough bolts are generally used for all woodwork. Finished bolts are only used in those cases where a close fit is absolutely essential. Where they are used the holes for them must be drilled to an exact fit with the bolts. They are often used as a substitute for rivets. In cases where rivets would be subjected to direct tension tending to pull off the rivet-heads finished bolts are more reliable.

Bolts are classed, first, according to the shape of the head, as *round* or *button, square, hexagon, octagon, saucered, countersunk-headed, clinch, collared, chamfered, diamond, convex*, etc.

Second, by some structural peculiarity of the head, as *eye, double-headed, hook, ring, T-headed*, etc.

Third, by the mode of securing, as *screw, fox, forelock, clinch, rivet, ray, bay, barb, jag key*, etc.

Fourth, by the nature and purpose of their application, as *assembling, fish, foundation, anchor, drive, fender, lewis, set, shackle, king, scarf*, etc.

A DOUBLE-ENDED BOLT has a thread and nut on each end.

A FLUSH BOLT is one whose head is let down even with the surface.

A FOUNDATION, ANCHOR, OR HOLDING-DOWN BOLT is a long, heavy bolt holding machinery or a structure down to masonry. The hole is generally filled with sulphur, lead, or Portland cement.

A FOX-BOLT is one with a split end into which a wedge is driven.

A HOOK-BOLT is one with a hook head.

A KEY-BOLT is secured by a cotter or wedge passing through a slot in the shank.

A LEWIS-BOLT is used for lifting large blocks of stone.

A RING-BOLT is one which has an eye for receiving a ring.

A SCREW-BOLT is one having a screw-thread on the whole or a considerable portion of its length.

A DRIFT-PIN is one used to expel another. Used also in rivetting to bring the holes fair for the entrance of the rivet.

DRIFT-BOLTS are made both round and square.

Round drift-bolts are superior to square bolts.

Round drift-bolts should be driven in holes $\frac{13}{16}$ of their diameter, and square drift-bolts $\frac{7}{8}$ of their width.

TABLE 49.

EFFECT OF DIAMETER OF HOLES ON HOLDING POWER OF DRIFT-BOLTS.

Diameter of Hole.	Tenacity per 1 Inch Length in Wood.		
	Yellow Pine.		White Oak.
	Round.	Square.	
12/16	400	600	1133
13/16	788	675	2499
14/16	633	777	1778
15/16	375	710	1301

WASHERS are flat disks of iron placed under the nut of a bolt.

The average relative holding power of drift-bolts, yellow pine being one, is in oak 3.1.

The resistance to drawing a drift-bolt varies very nearly with the depth to which it is driven.

NUTS must fit snugly, and the thread must pass through the nut and project at least one quarter of an inch.

The heads and nuts must rest squarely upon the surface of the material which they unite. When the nuts or heads come against inclined surfaces bevelled washers of cast iron are used.

The inspector must see that bolts of sufficient length are furnished and used. Cases are on record where bolts too short to pass through the nuts have been given a correct appearance by screwing threaded bolt-ends into the exposed sides of the nuts. Dummy bolts, that is, heads and screwed ends inserted in each side of the material to be joined, have been used to save both labor and material. Inspectors should keep a close watch for this practice.

TABLE 50.

STANDARD DIMENSIONS OF SCREWS, HEADS, AND NUTS.

Diam. of bolt.	Short diam. Rough.	Short diam. Finish.	Long diam. Rough.	Long diameter Rough.	Thickness. Rough Nut.	Thickness Rough. Head.	[illegible] ness Finish. Both.
1/4	1/3	7/16	87/64	7/10	1/4	1/4	8/16
5/16	19/82	17/82	11/16	10/12	5/16	19/64	1/4
8/8	11/16	5/8	51/64	63/64	8/8	11/82	5/16

TABLE 51.

WEIGHT AND DIMENSIONS OF BOLTS AND NUTS.

Diameter of Bolt.	Size of Nut.			Weight of Head and Nut or Two Nuts.		Weight of Bolt Bodies per Inch of Length.
	Width.	Thick.	Hole.	Square.	Hexagonal.	
¼	½	¼	7/32	.034	.031	.014
5/16	⅝	5/16	9/32	.067	.055	.021
⅜	¾	⅜	11/32	.110	.105	.031
7/16	⅞	7/16	13/32	.181	.171	.042
½	1	½	7/16	.280	.233	.055
9/16	1⅛	9/16	½	.369	.335	.069
⅝	1¼	⅝	9/16	.545	.475	.085
¾	1⅜	¾	21/32	.776	.678	.123
⅞	1⅝	⅞	25/32	1.34	1.14	.167
1	1¾	1	⅞	1.75	1.48	.218
1⅛	2	1⅛	15/16	2.47	....	.276
1¼	2¼	1¼	1 1/16	3.74	.....	.341
1⅜	2¾	1⅜	1 3/16	5.85	.....	.412
1½	3	1½	1 5/16	7.59	.....	.491
1⅝	3¼	1⅝	1 7/16	9.48	.....	.576
1¾	3½	1¾	1 9/16	11.9	.....	.668
1⅞	3¾	1⅞	1 11/16	14.1	.....	.767
2	4	2	1 13/16	18.6	.....	.872
2⅛	4	2⅛	1 ⅞	18.9	.....	.985
2¼	4	2¼	2	19.3	.....	1.104

In ordering bolts give the diameter, length under head, and length of thread required.

TABLE 52.

WEIGHT AND STRENGTH OF BOLTS.

Ends Enlarged, or Upset.				Ends Not Enlarged.		Ends Enlarged, or Upset.				Ends Not Enlarged.	
Diam. of Shank.	Weight per Foot Run.	Breaking Strain.	Breaking Strain.	Diam. of Shank.	Weight per Foot Run.	Diam. of Shank.	Weight per Foot Run.	Breaking Strain.	Breaking Strain.	Diam. of Shank.	Weight per Foot Run.
In.	Lbs.	Tons.	Lbs.	In.	Lbs.	In.	Lbs.	Tons.	Lbs.	In.	Lbs.
1/8	.0414	.245	549	......	.....	1 3/4	8.10	45.7	102368	2.14	12.0
3/16	.093	.553	1239	......	.....	13/16	8.69	49.0	109760	2.22	12.9
1/4	.165	.983	2202	.35	.321	7/8	9.30	52.5	117600	2.30	13.8
5/16	.258	1.53	3427	.43	.452	15/16	9.93	56.0	125440	2.38	14.7
3/8	.372	2.21	4950	.50	.654	2	10.6	59.7	133728	2.45	15.7
7/16	.506	3.00	6720	.58	.897	1/8	12.0	63.8	142912	2.59	17.5
1/2	.661	3.93	8803	.66	1.14	1/4	13.4	71.6	160384	2.73	19.5
9/16	.837	4.97	11133	.73	1.41	3/8	14.9	79.7	178528	2.88	21.6
5/8	1.03	6.14	13754	.80	1.67	1/2	16.5	88.4	198016	3.02	23.9
11/16	1.25	7.42	16621	.88	2.03	5/8	18.2	97.4	218176	3.16	26.1
3/4	1.49	8.83	19779	.96	2.41	3/4	20.0	106.9	239456	3.30	28.5
13/16	1.75	10.4	23296	1.04	2.81	7/8	21.9	116.8	261632	3.45	31.1
7/8	2.03	12.0	26880	1.12	3.26	3	23.8	127.2	284928	3.60	33.9
15/16	2.33	13.8	30012	1.20	3.77	1/4	27.9	141.0	315840	3.86	39.1
1 in.	2.65	15.7	35168	1.27	4.27	1/2	32.4	163.6	366464	4.12	44.4
1/16	2.99	16.8	37632	1.35	4.77	3/4	37.2	187.7	420448	4.41	51.0
1/8	3.35	18.9	42336	1.42	5.28	4	42.3	213.6	478464	4.70	57.8
3/16	3.73	21.1	47264	1.49	5.81	1/4	47.8	227.0	508480	4.98	65.2
1/4	4.13	23.3	52192	1.55	6.39	1/2	53.6	254.5	570080	5.25	72.9
5/16	4.56	25.7	57568	1.64	7.04	3/4	59.7	283.5	635040	5.53	80.5
3/8	5.00	28.2	63168	1.72	7.74	5	66.1	314.2	703808	5.80	88.1
7/16	5.47	30.8	68992	1.80	8.48	1/4	72.9	324.7	727328	6.08	97.0
1/2	5.95	33.6	75264	1.87	9.20	1/2	80.0	356.4	798336	6.36	106.
9/16	6.46	36.4	81536	1.94	9.88	3/4	87.5	389.5	872480	6.63	116.
5/8	6.99	39.4	88256	2.00	10.6	6	95.2	424.1	949984	6.90	126.
11/16	7.53	42.5	95200	2.07	11.3						

TABLE 53.

PLATE-IRON WASHERS.

Diameters.		Thickness Birmingham Wire Gauge.	Number of Washers per Pound.	Diameters.		Thickness Birmingham Wire Gauge.	Number of Washers per Pound.
Washer. Inches.	Bolt-hole. Inches.			Washer Inches.	Bolt-hole. Inches.		
1/2	1/4	18	543	1 3/4	11/16	10	17.
5/8	5/16	16	228	2	13/16	10	10.7
3/4	5/16	16	147	2 1/4	15/16	9	8.7
7/8	3/8	16	123	2 1/2	1 1/16	9	6.8
1	7/16	14	70	2 3/4	1 1/4	9	4.7
1 1/4	1/2	14	50	3	1 3/8	9	3.7
1 3/8	9/16	12	30	3 1/2	1 1/2	9	3.0
1 1/2	5/8	12	25.7				

Rivets.

Rivets are cylindrical pieces of metal with a solid head at one end, made of wrought iron, mild steel, or copper, either by hand or machinery.

Iron and steel rivets are chiefly used to connect plates of iron and steel. They are preferable to small bolts, because, being hammered close to the face of the plate, they hold more tightly, and the shanks of rivets are not so likely to become oxidized as those of bolts; moreover, as rivets are nearly always fixed when hot, they contract in cooling and draw the plates together with great force.

SIZE OF RIVETS.—The size of the rivet shown on the plans is the size of the cold rivet before heating. The diameter of the finished rivet should not be more than $\frac{1}{16}$ inch greater than the cold rivet. The heated rivet should not drop into the hole, but should require a slight pressure to force it in.

Rivets are described by the diameter and length in even eighths of an inch.

The length of a rivet is determined by adding together the grip of the rivet, i. e., the thickness of the plates or parts through which the rivet is to be driven, the length of metal required to form one head, and $\frac{1}{32}$ of an inch for each joint between the plates to allow for uneven surfaces which prevent closer contact. The length thus found must be increased by about 9 per cent to allow for filling the rivet-hole, which is usually $\frac{1}{16}$ inch larger in diameter than the rivet; thus the length of rivet required to join three half-inch plates would be $2\frac{7}{8}$ inches.

For countersunk heads add one half the diameter of the rivet for the head.

The height of the head of a snap-rivet should be about $\frac{5}{8}$ of the diameter of the shank, and the diameter of the head should be from $1\frac{1}{2}$ to twice that of the shank.

TABLE 54.

LENGTH OF RIVET-SHANK REQUIRED TO FORM HEAD.

Plain Rivets.						Countersunk Rivets.					
Grip in Inches.	Diameter in Inches.					Grip in Inches.	Diameter in Inches.				
	½	⅝	¾	⅞	1		½	⅝	¾	⅞	1
	Length in Inches.						Length in Inches.				
½	1⅛	1¾	1⅞	2	2⅛	½	1⅛	1¼	1¼	1⅜	1⅜
⅝	1⅝	1⅞	2	2⅛	2¼	⅝	1¼	1⅜	1⅜	1½	1½
¾	1¾	2	2⅛	2¼	2⅜	¾	1⅜	1½	1½	1⅝	1⅝
⅞	1⅞	2⅛	2¼	2⅜	2½	⅞	1½	1⅝	1⅝	1¾	1¾
1	2	2¼	2⅜	2½	2⅝	1	1⅝	1¾	1¾	1⅞	1⅞
1⅛	2⅛	2⅜	2½	2⅝	2¾	1⅛	1¾	1⅞	1⅞	2	2
1¼	2¼	2½	2⅝	2¾	2⅞	1¼	1⅞	2	2	2⅛	2⅛
1⅜	2⅜	2⅝	2¾	2⅞	3	1⅜	2	2⅛	2⅛	2¼	2¼
1½	2⅝	2⅞	3	3⅛	3¼	1½	2⅛	2¼	2⅜	2⅜	2½
1⅝	2¾	3	3⅛	3¼	3⅜	1⅝	2¼	2⅜	2½	2½	2⅝
1¾	2⅞	3⅛	3¼	3⅜	3½	1¾	2⅜	2½	2⅝	2⅝	2¾
1⅞	3	3¼	3⅜	3½	3⅝	1⅞	2½	2⅝	2¾	2¾	2⅞
2	3⅛	3⅜	3½	3⅝	3¾	2	2⅝	2¾	2⅞	2⅞	3
2⅛	3¼	3½	3⅝	3¾	3⅞	2⅛	2¾	2⅞	3	3	3⅛
2¼	3⅜	3⅝	3¾	3⅞	4	2¼	2⅞	3	3⅛	3⅛	3¼
2⅜	3½	3¾	3⅞	4	4⅛	2⅜	3	3⅛	3¼	3¼	3⅜
2½	3⅝	3⅞	4	4⅛	4¼	2½	3⅛	3¼	3⅜	3⅜	3½
2⅝	3¾	4	4⅛	4¼	4⅜	2⅝	3¼	3⅜	3½	3½	3⅝
2¾	3⅞	4⅛	4¼	4⅜	4½	2¾	3⅜	3½	3⅝	3⅝	3¾
2⅞	4	4¼	4⅜	4½	4⅝	2⅞	3½	3⅝	3¾	3¾	3⅞
3	4¼	4½	4⅝	4¾	4⅞	3	3¾	3¾	3⅞	4	4⅛
3⅛	4⅜	4⅝	4¾	4⅞	5	3⅛	3⅞	3⅞	4	4⅛	4¼
3¼	4½	4¾	4⅞	5	5⅛	3¼	4	4⅛	4⅛	4¼	4⅜
3⅜	4⅝	4⅞	5	5⅛	5¼	3⅜	4⅛	4¼	4¼	4⅜	4½
3½	4¾	5	5⅛	5¼	5⅜	3½	4¼	4⅜	4⅜	4½	4⅝
3⅝	4⅞	5⅛	5¼	5⅜	5½	3⅝	4⅜	4½	4½	4⅝	4¾
3¾	5	5¼	5⅜	5½	5⅝	3¾	4½	4⅝	4⅝	4¾	4⅞
3⅞	5⅛	5⅜	5½	5⅝	5¾	3⅞	4⅝	4¾	4¾	4⅞	5
4	5¼	5½	5⅝	5¾	5⅞	4	4¾	4⅞	5	5	5⅛
4⅛	5⅜	5⅝	5¾	5⅞	6	4⅛	4⅞	5	5⅛	5⅛	5¼
4¼	5½	5¾	5⅞	6	6⅛	4¼	5	5⅛	5¼	5¼	5⅜
4⅜	5⅝	5⅞	6	6⅛	6¼	4⅜	5⅛	5¼	5⅜	5⅜	5½
4½	5⅞	6⅛	6¼	6⅜	6½	4½	....	....	....	5½	5⅝
4⅝	6	6¼	6⅜	6½	6⅝	4⅝	....	....	....	5⅝	5¾
4¾	6⅛	6⅜	6½	6⅝	6¾	4¾	....	....	....	5¾	5⅞
4⅞	6¼	6½	6⅝	6¾	6⅞	4⅞	....	....	....	5⅞	6
5	6⅜	6⅝	6¾	6⅞	7	5	....	....	....	6	6⅛
5⅛	6½	6¾	6⅞	7	7⅛	5⅛	....	....	....	6⅛	6¼
5¼	6⅝	6⅞	7	7⅛	7¼	5¼	....	....	....	6¼	6⅜

Form of Rivets.—There are various names given to rivets according to the shape to which the point is formed.

Button or *cup-ended rivets* are names given to rivet-heads formed with the "snap."

Hammered rivets have points finished to a conical form by hammering only.

Countersunk rivets are those in which the point is hammered down while hot flush with the surface of the plate.

PITCH OF RIVETS.—The "pitch" of rivets is their distance from centre to centre.

SINGLE-RIVETING consists of a single row of rivets uniting plates in any form of joint.

DOUBLE-RIVETING is that in which the plates are united by a double row of rivets. Double-riveting is designated as *chain*, *staggered*, or *zigzag*. *Chain* riveting is formed by parallel lines of rivets. *Staggered* or *zigzag* riveting consists of lines of rivets so placed that the rivets in each line divide the spaces between the rivets in the adjacent line or lines.

Triple- and *quadruple-*riveting are formed by 3 or 4 rows of rivets, and may be either chain or staggered.

The joints made in riveting are termed *lap-joints* when the plates overlap one another; *fish-* and *butt joints* when the ends of the pieces to be united meet or butt evenly against one another, the joint being made with a cover-plate on either one or both sides.

Table 55.

WEIGHT OF RIVETS AND ROUND-HEADED BOLTS WITHOUT NUTS PER 100.

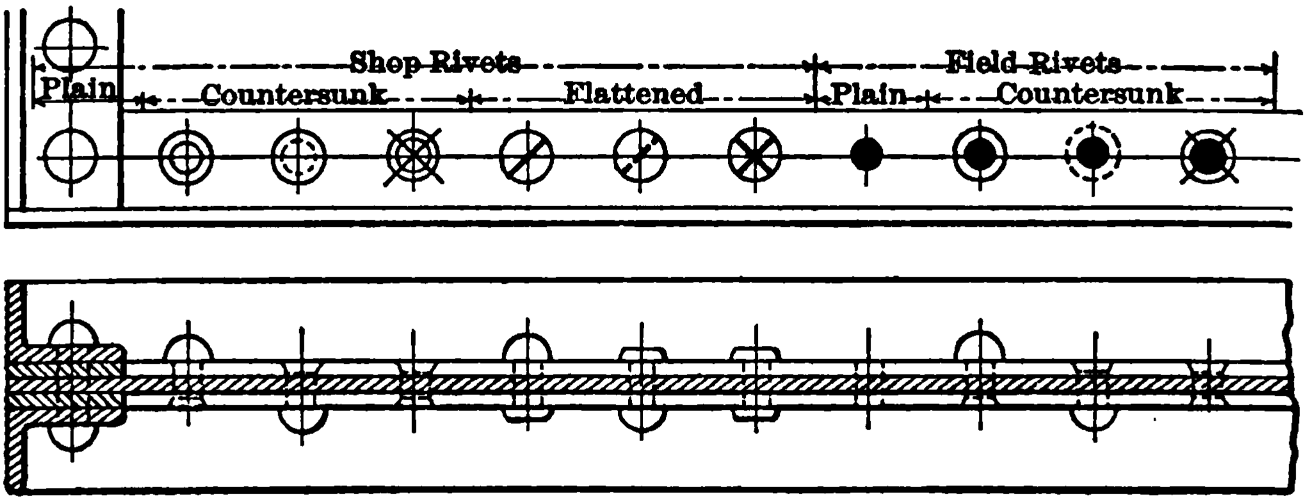
Length from under head. One cubic foot weighing 480 lbs.

Length of rivet under head.	Diameter of rivet in inches.							
	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
1 1/4	5.4	12.5	21.2	28.0	42.5	64.6	91.0	121.8
1 3/8	5.9	13.1	22.4	29.5	44.6	67.3	94.5	127.0
1 1/2	6.3	13.7	23.5	31.0	46.7	69.9	97.9	132.4
1 5/8	6.7	14.4	24.7	32.7	48.9	72.8	101.2	137.2
1 3/4	7.0	15.1	26.0	34.2	51.0	75.0	104.0	141.1
1 7/8	7.3	15.8	27.1	35.6	53.3	77.8	107.3	145.0
2	7.6	16.5	28.3	37.0	55.2	81.3	110.6	149.2
2 1/8	7.9	17.2	29.6	38.4	57.5	84.1	113.9	154.0
2 1/4	8.3	17.8	31.0	39.8	59.5	86.9	118.2	158.2
2 3/8	8.8	18 4	32.1	41.5	61.7	89.5	122.1	163.0
2 1/2	9.1	19.1	33.2	43.2	63.9	92.2	125.5	168.1
2 5/8	9.5	19.8	34.4	44.8	66.0	94.8	129.0	172.0
2 3/4	9 8	20.5	35.4	46.1	68.2	97.3	132.4	176.0
2 7/8	10.2	21.2	36.1	47.7	70.1	100.0	135.9	180.3
3	10.6	21.9	37.0	49.0	72.1	102.5	139.4	184.9
3 1/8	11.0	22.7	38.2	50.6	74.0	105.1	142.5	189.0
3 1/4	11.3	23.4	39.1	52.1	76.2	107.8	146.1	194.1
3 3/8	11.7	24.0	40.2	53.7	78.5	110.4	149.6	198.1
3 1/2	12.1	24.7	41.0	55.2	80.2	112.9	153 0	202.0
3 5/8	12.5	25.3	42.0	56.7	82.4	115 5	156.5	206.1
3 3/4	12.8	26.0	42.9	58.1	84.3	118.0	160.1	210.2
3 7/8	13.2	26.6	44.1	60.0	86.5	120.6	163.4	214.1
4	13.6	27.2	45.1	61.5	88.7	123.2	166.9	218.0
4 1/8	14.0	28.0	46.2	63.2	91.0	125.7	170.2	221.9
4 1/4	14.4	28.9	47.1	65.1	93.4	128.3	173.6	225.8
4 3/8	14.9	29.5	48.0	66.6	95.1	131.0	176.9	229.5
4 1/2	15.3	30.2	48.9	68.0	97.3	133.6	180.3	234.9
4 5/8	15.7	30.9	49.8	69.2	99.5	136.2	183.8	239.0
4 3/4	16.1	31.6	51.0	70.9	101.1	138.8	187.2	244.0
4 7/8	16.5	32.2	52.1	72.5	103.4	141.3	191.0	248.2
5	17.0	32.9	53.3	74.2	105.2	144.0	194.5	252.1
5 1/4	17.6	33.9	55 6	77.2	109.8	150.0	201.3	260.9
5 1/2	18.2	35.1	56.8	80.3	114.1	155.7	208.1	269.7
5 3/4	18.9	36.6	58.0	83.2	118.0	161.0	214.9	278.3
6	19.7	37.7	59.9	86.1	122.7	166.1	222.0	287.1
7	22.3	42.8	67.0	98.4	141.1	188.0	250.0	319.0
8	24.7	48.0	76.1	112.2	157.9	213.0	278.1	353.4
9	27.4	53.9	83.9	124.0	172 5	234.0	304 9	388.4
10	31.0	59.0	90.8	135.9	188.1	254.3	332.1	421.0
12	37.7	70.9	108.4	160.0	221.5	298.3	387.9	490.0

For length of shank required to form rivet-head see p. 568.

Field-rivets are those driven in a structure after it is in place. Wrought iron is generally used for field-rivets, because it is less liable to injury from overheating and from the decrease in temperature due to the loss of time in passing from the forge to the riveters. Steel properly heated would cool to a point below which it is not advisable to do any work upon it, and if heated to a temperature sufficient to compensate for the cooling it would be subjected to such oxidation as would make it "red-short."

Conventional Rivet-signs.—The size and location of rivets are usually marked on the working drawings in figures, but the form of the head, as well as whether they are to be driven in the shop or field, are indicated by conventional signs as shown by the following figures:



CONVENTIONAL RIVET-SIGNS.

Riveting.—The process of riveting is performed either by hand or by machines, operated by air-, steam-, or water-power. In either method it consists of heating the rivet, passing it through the holes in the pieces to be united while hot, and then forging another head out of the projecting shank.

HAND-RIVETING.—In hand-riveting the forging is performed with hammers having flat faces. The end of the shank is upset and hammered until it forms a convex point. This is generally finished with a tool called a "snap," which is hollowed out to form a cup that will fit the point of the rivet. A heavy sledge-hammer called a "cupping"-hammer is used to strike the snap. The snap is generally used just as the rivet is losing its red heat. During the forging the rivet is held in place by an iron bar or "dolly," one end of which is hollowed out in the form of a cup that fits on the head of the rivet. "Spring"-dollies should be used where possible, especially for heavy pieces. For light work simple hand-dollies weighing from 15 to 25 pounds are used. The man who holds the dolly is called the "holder up."

MACHINE-RIVETING is cheaper and superior to hand-riveting. The steady pressure brought by the machine upon the rivet not only forms the head, but compresses and enlarges the shank, so that it is squeezed into and thoroughly fills up all the irregularities of the holes. The superiority of machine-riveting is strikingly shown when rivets have to be taken out. After the head is cut off a hand-forged rivet may be easily driven out, but a machine-driven rivet must, as a rule, be drilled out.

Machine-driven rivets can generally be easily distinguished from those formed by hand; the latter are covered with marks caused by the hammer and shifting of the snap during the forging, while on a machine-riveted head there is generally a burr, caused by the die having caught the rivet a little out of the centre.

PRESSURE REQUIRED FOR RIVETING.—It has been found in girder-work that for red-hot rivets of iron or soft steel, with length of grip not exceeding three diameters, a pressure of 50 tons per square inch of rivet-section has been sufficient to completely fill the hole. Longer rivets require higher pressure, and in extreme cases this pressure may be doubled to secure solidity.

For cold-riveting the pressure required is about 300,000 lbs. per square inch of rivet-section.

The pressures usually employed are as follows:

Inches:	5/8	3/4	7/8	1	1 1/8	1 1/4
Tons:	25	33	50	66	75	100

CALKING is a process adopted when it is found that the rivets are loose, or that the head or point of the rivet is not quite close to the plates, or that an opening exists between the plates themselves. The process consists in hammering down the edges of the head or point of the rivets until they indent and slightly penetrate the surface of the plates.

COLD RIVETING.—Very small iron and copper rivets are closed cold The iron used must be of the best quality.

Inspection of Riveting.

TESTS FOR RIVET-METAL.—The requirements of specifications vary considerably in regard to the properties of rivet-metal; a usual specification is as follows:

" Steel for rivets shall have, in test-pieces $\frac{3}{4}$ inch in diameter, an ultimate tensile strength of from 48,000 to 50,000 pounds per square inch; an elongation in 8 inches of 26 per cent.

" Heated uniformly to a light yellow and cooled in water at 82° F., it shall bend round a circle of diameter equal to one and a half times the thickness of the specimen without fracture.

" Full-size rivet-bars shall bend cold and double flat on themselves without sign of fracture on the convex side."

U. S. NAVY DEPARTMENT TEST.—From each lot (ton) twelve rivets are to be taken at random and submitted to the following tests: Four rivets to be flattened out cold under the hammer to a thickness of one half the diameter without showing cracks or flaws. Four rivets to be flattened out hot under the hammer to a thickness of one third the diameter without showing cracks or flaws; the heat to be the working heat when driven. Four rivets to be bent cold into the form of a hook with parallel sides without showing cracks or flaws.

Iron for rivets must be tough and soft, and specimens of the full diameter of the rivet must be capable of bending cold until the sides are in close contact without sign of fracture on the convex side of the curve.

A rivet of good iron when cut out of the work with a cold-chisel and hammer should show tough and fibrous and should not "fly"; if it does it indicates brittleness.

Essentials of Good Riveting.—*Rivet-holes.*—The holes in material to be riveted are either punched or drilled.

In whichever way they are formed it is important that they should be cut clean and true, and should fit exactly over one another. If they do not, irregularities are formed, which have to be forcibly removed by driving a steel "drift-pin" into them before inserting the rivet, thus injuring the material, enlarging the hole, and causing the rivet to fit loosely.

In punching holes examine the punches and dies and see that they are sharp and in perfect condition; good metal may be badly damaged by the use of imperfect punches and dies.

Holes should be punched from the side of the material that

will be exposed in the work; that is, the bevel of the hole must be away from the surfaces that are to be in contact.

It is the current practice to punch the holes $\frac{1}{16}$ inch larger than the rivet diameter. For work to be reamed it is usual to punch the holes from $\frac{1}{8}$ to $\frac{3}{16}$ inch smaller than the finished diameter, the holes being reamed to the proper size after the various parts are assembled.

The sharp edges or burr on the sides of the holes should be removed so as to form a fillet at the junction of the body and head of the finished rivet.

After reaming the hole should be entirely smooth, showing that the reaming-tool has everywhere touched the metal.

Heating Rivets.—The heating of rivets requires watching to prevent burning. There is no way of telling after a rivet has been driven whether it is burned, for the head may look perfectly good while the shank is badly damaged.

The burning of rivets is not always accidental; often if the rivet is so long as to more than fill the snap the heater will "waste" the end, that is to say, he will burn it so badly that it will crumble off.

Steel rivets require careful handling to prevent overheating and to avoid working them at too low a heat, or at what is called a "blue heat." They should be heated uniformly to a dull-red heat and the orange color should not be passed; they should be placed in the work immediately the proper temperature is reached and the head forged as rapidly as possible.

Iron rivets can be heated to the "waste" or "wash" heat, a temperature at which the intermingled slag in the metal begins to soak out from it without serious injury. Iron rivets should not be worked at a blue heat.

Iron rivets should not be raised above a dull red (by daylight), and should not be twice heated. Burned rivets are weak and brittle. A large number of rivets should not be put into the fire at once to save trouble: they are liable to be left too long and consequently burned.

For riveting by hand it is desirable that the head of the rivet should be even hotter than the point; otherwise the blows which are sufficient to expand the rivet and make it fill the hole near the point will not have much effect at the other end, and the rivet will not quite fill the hole near the head.

The forge in which the rivets are heated should be placed as close to the point of use as possible.

The two heads must be concentric, fit closely all around, and no impress on the metal around the head should be made in driving. The finished rivet-head should be without cracks.

Redriving cold rivets and calking of rivet-heads should not be permitted.

Loose Rivets are detected by striking the rivet a sharp blow on each side of the head with a hammer weighing about one pound, the handle to which should be quite small in the shank, so as to allow the absorption at this point of some of the spring of the hammer. When the handle is held at the proper point and the rivets are solid no jarring effect is felt in the hand. Practice soon enables one to detect loose rivets by means of the action of the handle where no rattling sound can be heard, and where no movement could be detected by the finger placed at the angle between the rivet-head and the web.

Loose rivets are frequently made to appear tight by going round the edges with a calking-tool. They will feel and sound all right and the marks of the calking-tool will not be noticed unless it is especially looked for. Loose rivets are also tightened by placing the "snap" sideways upon the rivet and striking it two or three blows with a sledge. It will then appear to be tight, partly because it is bent and partly because the snap cuts a ridge in the plate and forces the metal against the head. Rivets tightened in this way show this ridge below the head, but a similar mark will often be made in shaping the head of a perfectly tight rivet, so the inspector cannot condemn work simply because this mark appears, but such work should be regarded with suspicion, and a sharp watch kept upon the workman. It will also be advisable to have a few of the suspicious rivets cut out.

The "held-up" head should be closely examined; a rivet may be perfectly tight on the head, while in consequence of poor heating it may be readily moved on the "held-up" side. Besides, the riveter cannot tamper with that part of the rivet, and any marks there will show that he has been trying to conceal bad work.

Very often there is trouble with countersunk rivets driven by a machine. The reason is this: the rivets are a trifle too long. This excess material spreads out under the die and overlaps the hole. Being thin this edge hardens quickly, and then no amount of pressure will upset the body of the rivet any further. It will appear tight until chipped, when it is often found to be loose.

Drawings often require flat-head rivets in certain places where

there is not enough clearance for the hemispherical head, and yet where all the space obtained by countersinking is not necessary. On account of the difficulty mentioned above such rivet-heads less than $\frac{1}{4}$ inch in thickness should not be allowed. If left unchipped it cannot be known whether the rivet fills the hole or not.

MARKING RIVETS TO BE CUT OUT.—In marking rivets to be cut out the inspector should use a centre-punch or the stamping end of his hammer with which to mark the head of the rivet, which should then be painted with white paint. A mark should also be made on the material near the rivet, so that he may be able to find and test the new rivet.

CHAPTER III.

CONSTRUCTION.

I. EARTHWORK.

Definitions of Earthwork.

The term "earthwork" is applied to all the operations performed in the making of excavations and embankments. In its widest sense it comprehends work in rock as well as in the looser materials of the earth's crust.

CLASSIFICATION OF EARTHWORK. — Excavation is usually classified under the heads *Earth*, *Hardpan*, *Loose Rock*, and *Solid Rock*. For each of these classes a specific price is usually agreed upon, and an extra allowance is sometimes made when the haul or distance to which the excavated material is moved exceeds a given amount.

The characteristics which determine the class to which a given material belongs are usually described with clearness in the specifications, as:

Earth will include loam, clay, sand, and loose gravel.

Hardpan will include cemented gravel, slate, cobbles, and boulders containing less than one cubic foot, and all other matters of an earthy nature, however compact they may be.

Loose Rock will include shale, decomposed rock, boulders, and detached masses of rock containing not less than three cubic feet, and all other matters of a rock nature which may be loosened with the pick, although blasting may be resorted to in order to expedite the work.

Solid Rock will include all rock found in place in ledges and masses or boulders measuring more than three cubic feet, and which can only be removed by blasting.

PROSECUTION OF EARTHWORK.—No general rule can be laid down for the exact method of carrying on an excavation and disposing of the excavated material. The operation in each case can only be determined by the requirements of the contract, character of the material, magnitude of the work, length of haul, etc.

Duty of Inspector.—The duty of the inspector of earthwork is to see that the excavations are made to the depths and widths

marked on the plans or directed by the engineer; that the sides of excavations, when required, are properly sheathed and braced so as to prevent slips and to afford protection to the workmen; that the excavated material is deposited in the manner prescribed by the specifications and within the lines and with the slopes indicated by the plans, etc.

The inspector should keep a record of the number of men and vehicles employed. On some works he will be required to determine the class to which the excavated material belongs, and sometimes its amount.

SLOPES OF EARTHWORK.—The sides of excavations and embankments are finished with slopes corresponding to the angle of repose of the material; that is, the angle at which the friction among the particles is sufficient to resist motion.

The angles of repose for different earths are given in Table 56. But for all practical purposes it may be said that all earths, sand, and gravel stand at a slope of 33 degrees 41 minutes, or 1½ to 1. Rock is finished either vertical or at a slope of ¼ to 1.

TABLE 56.

NATURAL SLOPES OF EARTHS (WITH HORIZONTAL LINE).

Gravel (average)	40 degress
Dry sand	38 "
Wet "	22 "
Vegetable earth	28 "
Compact earth	50 "
Shingle	39 "
Rubble	45 "
Clay (well drained)	45 "
" (wet)	16 "

TABLE 57.

LENGTHS AND ANGLES OF SLOPES.

Slope.	Angle with Horizon.	Length. (Height taken as 1.00.)	Slope.	Angle with Horizon.	Length. (Height taken as 1.00.)
¼ : 1	75° 58′	1.0307	1½ : 1	33° 41′	1.802
½ : 1	63 26	1.118	1¾ : 1	29 44	2.016
¾ : 1	53 8	1.25	2 : 1	26 34	2.236
1 : 1	45 0	1.4142	3 : 1	18 26	3.162
1¼ : 1	38 40	1.6	4 : 1	14 2	4.124

The sides of an excavation will stand for a short time with a vertical face for a certain depth below its upper edge. That depth is greater the greater the adhesion of the earth as compared with its heaviness; the adhesion is increased by a moderate degree of moisture, but diminished by excessive wetness.

The approximate depth at which earths will thus stand are as follows:

Earth.		Greatest Depth of Tem. Vert. Face.
Clean dry sand and gravel	from	0 to 1 foot
Moist sand and ordinary surface-mould	"	3 " 6 feet
Clay (ordinary)	"	10 " 16 "
Compact gravel,	"	10 " 15 "

Form of Side Slopes.—The natural, strongest, and ultimate form of earth slopes is a concave curve in which the flattest portion is at the bottom. This form is very rarely given to the slopes in constructing them; in fact, the reverse is often the case, the slopes being made convex, thus saving excavation for the contractor and inviting slips.

In cuttings exceeding 10 feet in depth the forming of concave slopes will materially aid in preventing slips, and in any case they will reduce the amount of material which will eventually have to be removed when cleaning up. Straight or convex slopes will continue to slip until the natural form is attained.

Increase and Shrinkage of Excavated Material.

All materials when excavated increase in bulk, but after being deposited in banks subside or shrink (rock excepted) until they occupy less space than in the pit from which excavated.

The shrinkage of the different materials is about as follows:

Gravel	8 per cent
Gravel and sand	9 " "
Clay and clay earths	10 " "
Loam and light sandy earths	12 " "
Loose vegetable soil	15 " "
Puddled clay	25 " "

Rock, on the other hand, increases in volume by being broken up, and does not settle again into less than its original bulk. The increase may be taken at 50 per cent.

Thus an excavation of loam measuring 1000 cubic yards will form only about 880 cubic yards of embankment, or an embank-

ment of 1000 cubic yards will require about 1120 cubic yards measured in excavation to make it. A rock excavation measuring 1000 yards will make from 1500 to 1700 cubic yards of embankment, depending upon the size of the fragments.

The lineal settlement of earth embankments will be about in the ratio given above; therefore either the contractor should be instructed in setting his poles to guide him as to the height of grade on an earth embankment to add the required percentage to the fill marked on the stakes, or the percentage may be included in the fill marked on the stakes. In rock embankments this is not necessary.

Excavation.

The prosecution of an excavation comprises the "loosening" of the compact earth and its removal.

LOOSENING EARTH.—The loosening is effected in such materials as sand and loose gravel, soft earth and loam, by ploughs if the area is of sufficient extent; if in trenches by the shovel alone. The stiffer earths and soft rocks are loosened with picks, crowbars, and wedges, the harder earths and solid rock by blasting. Excavation of soft material under water is performed by machines called dredges. Rock under water is removed by blasting and dredging.

The *rapidity* with which an excavation can be made depends upon the difficulty of getting out the earth.

With hard clay, requiring two picks to a shovel, and with a small surface to work upon, two carts upon an ordinary road will take away all that a dozen men can get out; while with an easy soil, where one pick will keep half a dozen shovels busy, a larger number of vehicles will be required, or a quicker haul, which may be obtained by putting down a track. The less the haul, or the greater the speed of transport, the fewer may be the number of vehicles to remove a given amount of material. The chief point to be gained is to arrange the different classes of laborers so that none shall be kept waiting. Everything depends upon the tact for management possessed by the overseer.

The *amount* of ordinary earth loosened by a plough and team of horses is from 20 to 40 cubic yards per hour.

By the pick per man:

Clay or cemented gravel....	1 yard per hour
Loam and loose gravel............	2 to 3 yards per hour
Light sand....	4 " 6 " " "

By blasting:

One pound of black powder in small blasts will loosen about $4\frac{1}{2}$ tons of hard rock, in large blasts about $2\frac{1}{4}$ tons; one pound of dynamite from 6 to 10 tons.

REMOVING EARTH.—The removal of the loosened material is effected by throwing or "casting" with a shovel when the horizontal distance does not exceed 12 feet and the vertical 6 feet.

By shovelling into wheelbarrows when the distance is under 200 feet.

By shovelling into one-horse carts or two-horse trucks or dump-wagons when the distance is great.

In excavating a large area of light depth in moderately compact material the loosening is performed with ploughs, and the removal with scrapers, either drag or wheeled, which automatically pick up the loosened material.

In earth excavations of sufficient magnitude steam-shovels are employed for loosening and loading the loosened material into dump-cars running on a track and hauled by horses or locomotives.

The *quantity* of material which a man can shovel into a vehicle in a given time depends upon the weight of the material.

The average quantity shovelled into a cart per man per hour is:

Loose earth or sand	2.0 cubic yards
Clay and heavy soils	1.7 " "
Rock	1.0 cubic yard

The average speed of horses in hauling is about 200 ft. per minute.

The economical length of haul with drag-scrapers is about 150 ft., wheeled scrapers 500 ft., wheelbarrows 250 ft., one-horse dump-carts 600 ft., two-horse dump-wagons 1000 ft. For hauls exceeding a thousand feet a track of light rails with dump-cars drawn by horses or light locomotives is the most economical.

The capacity of the vehicles used for moving excavated material is about as follows:

Wheelbarrows	3 to 4 cubic feet
1-horse dump-carts	18 " 22 " "
2 " dump-wagons	27 " 45 " "
Drag-scrapers	3 " 7 " "
Wheel-scrapers	10 " 17 " "
Dump-cars on rails	27 " 81 " "

Rock Excavation.

Excavation in hard rock is usually performed by means of some explosive inserted in a hole bored in the rock, which when ignited loosens the mass and permits of its being broken up into pieces easily removed.

Drilling.—Holes for blasting rock are bored either by hand- or machine-drills. Shallow cuts, loose boulders, etc., are more cheaply bored by hand, but deep and extensive cuttings are more economically carried out by the use of machine-drills operated either by steam, compressed air, or electricity.

HAND-DRILLING is divided into three classes, viz., *single-handed*, in which one man with a set of short drills and a hand-hammer bores the holes; *double-handed*, in which one man holds and turns the drill while one or two men strike it alternately; and *churn-* or *jumper-drilling*, in which one or two men use a drill called a *churn* or *jumper*—the operation consists in raising the drill, turning it slightly, and letting it drop.

The speed with which holes may be bored in rock varies of course with the hardness of the rock and the diameter of the hole. The smaller the diameter of the hole the greater the depth that can be bored in a given time; and the depth will be greater in proportion than the decrease of the diameter.

The average rate of progress made by a good drillman working a churn-drill in granite and the harder rocks is about as follows:

Diam. of Drill. Inches.	Depth bored per Hour. Inches.
3	4
$2\frac{1}{2}$	5
$2\frac{1}{4}$	6
2	8
$1\frac{3}{4}$	10

When the hole exceeds four feet in depth two men are required to operate the drill.

MACHINE-DRILLING.—Machine-drills bore holes from $\frac{3}{4}$ to 6 inches in diameter. The rate of progress is controlled by the same conditions as hand-drilling, and ranges from three to ten feet per hour, depending on the character of the rock and the size of the machine.

SIZE OF HOLES.—The diameter and depth of the hole will vary with the quantity of rock to be loosened, and also with the strength of the explosive to be used.

Blasting. — The quantity of explosive required to loosen a given amount of rock depends upon the character of the rock, the kind of the explosive, and largely upon a judicious selection of the direction of the hole with respect to the "lay" of the strata.

It is usual to allow $\frac{3}{4}$ of a pound of black powder to each cubic yard of solid rock, or 1 lb. of dynamite to 8 or 10 yards. The actual quantity of explosive required will vary with the nature of the rock and its degree of compactness or looseness, the latter requiring the largest quantity.

The quantity of explosive required for a given blast may be approximately calculated by the following formula:

If $E =$ the quantity of explosive in pounds, and
$L =$ the line of least resistance that is, the shortest distance from the center of the charge to the surface of the rock, then

$E = CL^3$;
$C = .032$ for blasting powder;
$= .005$ " " cotton;
$= .003$ " nitroglycerine and dynamite.

In blasting no loud report should be heard nor stones be thrown out. The best effect is produced when the report is trifling, and when the mass is lifted and thoroughly fractured without the projection of fragments. If the rock be only shaken by a blast and not moved outward, a second charge in the same hole will be very effective.

Explosives.—Most of the explosives used consist of a powdered substance, partly saturated with *nitroglycerine*, a fluid produced by mixing glycerine with nitric and sulphuric acids.

Pure *nitroglycerine* at 60° F. has a specific gravity of 1.6. It is odorless, nearly or quite colorless, and has a sweetish burning taste. It is poisonous, even in very small quantities. Handling it is apt to cause headaches. It is insoluble in water. At about 306° F. it takes fire, and if unconfined burns harmlessly, unless it is in such quantity that a part of it before coming in contact with air becomes heated to the exploding-point, which is about 380° F. From its liability to explosion through accidental per-

cussion, leakage, etc., it is rarely used in the liquid state in ordinary quarrying or blasting.

DYNAMITE is the name applied to any explosive which contains nitroglycerine mixed with a granular absorbent. The nitroglycerine undergoes no change in composition by being absorbed; the office of the absorbent is to act as a cushion and so protect the nitro-glycerine from percussion.

Dynamite is classed according to the percentage of nitroglycerine present. No. 1 contains 75 per cent, and from that down to 15 per cent.

Dynamite is slow to catch fire; when ignited in the air and unconfined it burns fiercely; if in large quantity or partly confined explosion may ensue.

Dynamite of all grades freezes at about 42° F. When in this condition it cannot be completely exploded, and must be thawed before use. This must be done gradually by leaving it in a warm room far from the fire, or by placing it in a metallic vessel, which is then placed in another vessel containing hot water. The water should not be hotter than can be borne by the hand.

Dynamite, giant powder, etc., is sold in cylindrical paper-covered cartridges from $\frac{7}{8}$ to 2 inches in diameter, and 6 to 8 inches long or longer. They are furnished to order of any required size, and are packed in boxes containing 25 or 50 lbs. each. The layers of cartridges are separated by sawdust.

Powder is fired by fuse, and dynamite either by a fuse with a detonating-cap, or by a cap connected to the wires of an electric battery; this method is employed where a number of charges are to be fired simultaneously and in blasting under water.

The cap or exploder used with fuse is a hollow copper cylinder, about $\frac{1}{4}$ inch in diameter and an inch or two in length. It contains from 15 to 20 per cent or more of fulminate of mercury mixed with other ingredients into a cement, which fills the closed end of the cap. The cap is called "single-force," "triple-force," etc., according to the quantity of explosive it contains.

The cap used with magneto-electric blasting apparatus is similar to that used with fuse, except that its mouth is closed with a cork of sulphur cement, through which pass the two wires leading from the electric machine.

The fuse used for dry work is designated as "single-tape fuse," for work in water "double-tape fuse."

Fuse burns at the rate of about three feet per minute.

Precautions to be observed in Blasting.

Although it is not desirable and not so effective to produce a great shattering and scattering of the broken rock, little attention is paid to this point in ordinary blasting operations. But in blasting near buildings or in the streets of cities special precautions must be taken to avoid projecting the fragments of rock to a great distance. This can be done by properly regulating the charge, and covering over and around the hole with brush and logs. A raft of logs chained together or a matting of ropes weighted with logs around the edges will prove effective for this purpose.

Judgment must be exercised as to the grade and quantity of explosive to be used in any given case. Where it is not objectionable to break the rock into small pieces, or where it is desired to do so for convenience of removal, the higher grades of dynamite should be selected. Where it is desired to get the rock out in large masses, as in quarrying, the lower grades are preferable.

For soft or decomposed rocks, sand, and earth the lower grades of dynamite are more suitable. They explode with less suddenness, and their tendency is rather to upheave large masses of rock, etc., than to splinter small masses of it.

For very difficult work in hard rock and for submarine blasting the high grades should be used. A small charge of these does the same execution as a larger charge of lower grade and of course does not require the drilling of so large a hole. In submarine work their sharp explosions is not deadened by the water.

In blasting with dynamite the charge should fill the hole as completely as possible. If water is not standing in the hole the cartridge should be cut open before insertion.

The higher grades of dynamite require but little tamping. Use a wooden tamping-bar, *never* a *metallic* one for any explosive.

If a charge of dynamite "hangs fire" it is dangerous to attempt to remove it. Remove the tamping all but a few inches in depth, and insert another cartridge and try again.

Dredging.

For excavating under water dredging-machines of various types are employed, as dipper-dredges, clam-shell dredges, ladder-and-bucket dredges, hydraulic dredges, etc.

The dredged material is usually removed in dumping-scows, except where the material is of such a character that a sand-pump or hydraulic dredge can be used; in this case the material is transported and deposited in place entirely by the force of a stream of water.

The limits of the area to be dredged are marked by ranges, which may be objects on shore, piles, or buoys. In tidal waters a plainly marked gauge is set up, when possible, at a point visible from the proposed cut. The required depth is measured from a fixed plane—in tidal waters that of mean low water.

The necessary channel-marks are placed under the direction of the engineer, and the contractor is usually made responsible for their care and preservation.

Duty of Inspector.—The inspector should be continually present during the prosecution of dredging operations. His duty comprises the determining of the proper position of the dredge, and if the width and depth of the cut are in accordance with the requirements. When scow measurement is to be used for ascertaining the amount of dredged material the capacity of the scows is carefully computed and the contractor is required to fill them each time to the same extent. The duty of determining whether the scows contain full loads devolves upon the inspector. In cases of partial loads he also decides as to the true amount.

It is usual to make an extra allowance of from one half to one foot for the irregularities left in the bottom by the dredge; that is, to insure that the minimum depth shall be attained.

Material dredged from outside the fixed lines or below the per mitted excess of a half or one foot is not paid for.

The increase of scow measurements over measurements in place is for rock 1½ to 2; very soft mud, 13 per cent; soft blue mud, 15 per cent; hard sand, 20 to 30 per cent.

Loose muck has been found to measure from 15 to 17 per cent *less* in the dredge-bucket than when in place. In hydraulic dredging, particularly where there is much fine, light material, place measurements equal or exceed scow measurements.

Embankments.

EMBANKMENTS are made in three ways: 1. In one layer. 2. In two or more thick layers. 3. In thin layers.

1. *In One Layer.*—This being the cheapest and quickest method consistent with stability is that followed in all earthworks in which there is no reason to the contrary.

2. *In Thick Layers.*—This process is used in embankments of great height. It consis's in completing the construction of the embankment up to a certain height by the process of dumping over the end, leaving that layer for a time to settle, and then making a second layer in the same way.

3. *In Thin Layers.*—This process consists in spreading the earth in horizontal layers of from 9 to 18 inches deep, and ramming or rolling each layer so as to make it compact and firm before laying down the next layer. Being a tedious and laborious process, it is used in special cases only, of which the principal are, the filling behind retaining walls, behind wings and abutments of bridges and culverts and over their arches, and the embankments of reservoirs for water.

In embankments of great magnitude and where water is to be retained by them all the vegetable matter and mould should be removed from the site before depositing the materials of the embankment.

In forming embankments on hillsides a common practice is to simply dump the material on the side slope; this method is insecure, the material so deposited is liable to slip and slide. The best method is to cut the surface of the natural slope into steps, the number of which will vary with the length of the slope—three feet apart is a good distance. No pains should be spared to give the material a secure hold, particularly at the toe of the slope.

The solidity of embankments which are not to be consolidated by rolling may be increased by filling from the sides towards the centre, keeping the sides high with a dip towards the centre.

Embankments formed by building a narrow bank as a roadway for the vehicles transporting the material, and then widening it by dumping the earth on the sides, are deficient in compactness, and are liable to slips and cracks, and will require a long time for complete consolidation.

When embankments are to be widened by the addition of new material the slopes of the old embankment should be cleaned from vegetable matter and mould and cut into steps or benches; otherwise the new material will not unite perfectly with the old.

II. Foundations.*

Definitions.

The term "foundation" is used to designate all that portion of any structure which serves only as a basis on which to erect the superstructure.

The term is sometimes applied to that portion of the solid material of the earth upon which the structure rests, and also to the artificial arrangements which may be made to support the base.

The object to be attained in the construction of any foundation is to form such a solid base for the superstructure that no movement shall take place after its erection. But all structures built of coarse masonry, whether of stone or brick, will settle to a certain extent, and with but few exceptions all soils will become compressed under the weight of almost any building.

The main object, therefore, is not to prevent settlement entirely, but to insure that it shall be uniform, so that after the structure is finished it will have no cracks or flaws, however irregularly it may be disposed over the area of its site.

Foundations are divided into two great classes, viz., *Natural* and *Artificial*. Each of them is subdivided into many kinds according to the material of the earth on which the structure is founded, the artificial arrangements required, and foundations under water.

Duty of Inspector.

As the stability and endurance of a structure depend upon the character of its foundation, it is of the utmost importance that the inspector concentrate his attention to its preparation, to see that the instructions of the engineer or architect and the requirements of the specifications are faithfully carried out, and to report without delay to his superior any probable source of failure that he may detect. There are two principal sources of failure to be

* For a complete discussion on the many and various methods of preparing foundations the reader is referred to "A Practical Treatise on Foundations," by W. M. Patton; "A Treatise on Masonry Construction," by I O. Baker; "Building Superintendence and Construction," and the "Architects' and Builders' Pocket-book," by F. E. Kidder, etc.

guarded against, viz., inequality of settlement, and lateral escape of the supporting material.

Natural Foundations.

Foundations constructed in situations where the natural soil is sufficiently firm to bear the weight of the intended structure.

The best natural foundation is a stratum of rock or compact gravel.

The foundation should be started from a uniform level, but if circumstances prevent it the ground must be carefully *benched*, i. e., cut into horizontal steps, so that the courses of masonry may all be perfectly level.

It must be borne in mind that all masonry-work will settle more or less according to the perfection and thickness of the joints, and therefore too much care cannot be exercised in the case of steps to bring up the foundation course to a uniform level with large blocks of stone or with concrete; otherwise the superstructure is liable to settle most over the deepest parts on account of the greater number of mortar-joints, and thus cause unsightly fractures.

Rock.—In preparing a rock surface see that all loose and decayed parts are cut away, that the surface is worked or cut into horizontal steps, that all hollows where the rock is solid are carefully filled with concrete.

Sand being practically incompressible forms an excellent foundation so long as it can be kept from shifting, but as it has no cohesion and acts like a fluid when exposed to running water, it must be treated with caution. Care must be exercised to keep surface-water from running into the trenches, and if necessary drains should be made at the bottom to carry away any water that may find its way in.

Clay is the most deceptive material to build upon. Its insecurity results from the position of its stratum, as well as its elasticity, from being mixed with marl, etc., and tendency to absorb moisture. In dry weather it is very firm, while in wet weather it is elastic and unreliable.

In building on clay great caution must be used to secure good drainage, both before and after the work is begun.

The foundation must be started below the frost-line, for the effect of frost on clay is very great.

The trenches must be protected from the entrance of water, and must be so arranged that water shall not remain in them.

In general the less a clay soil is exposed to the air and weather, and the sooner it is protected from exposure, the better for the work.

BEARING POWER OF SOILS.—*New York Building Laws*, 1892–96: "Good solid natural earth shall be deemed to safely sustain a load of 4 tons to the superficial foot, and the width of footing-courses shall be at least sufficient to meet this requirement."

Chicago Building Ordinances, 1893:

Pure clay, 15 ft. thick, without admixture of any foreign substance, excepting gravel	3500 lbs.
Dry sand, 15 ft. or more in thickness, and without admixture of clay, loam, or other foreign substance	4000 "
Clay and sand mixed	3000 "

LOADS ON FOUNDATIONS.—*Chicago Building Ordinances*, 1893:

	Per Sq. Ft.
Concrete foundations	8,000 lbs.
Foundation-piers of dimension stone	10,000 "
Brick piers in cement	18,000 to 25,000 "
Iron rails in concrete	12,000 "
Steel " " "	16,000 "
Piles	25 tons

Artificial Foundations.

The construction of foundations in compressible soils, quicksand, and under water oftentimes requires all the resources of the engineer, and causes no little trouble, anxiety, and expense. The methods employed are many and varying, comprising coffer-dams, cribs, caissons, hollow cylinders, timber and iron piles, pneumatic piles, freezing, and other processes.

CAISSONS are of two forms, the "erect" or "open" and the "inverted." The former is a strong water-tight box, having vertical sides and a bottom of heavy timber, in which the masonry is built, and which sinks as the masonry is added, until the bottom rests upon the foundation prepared for it.

The *inverted caisson* is also a strong water-tight box, open at the bottom and closed at the top, upon which the structure is built, and which sinks as the masonry is added. This style of caisson is usually aided in sinking by the pneumatic process, in which case it is called a pneumatic caisson.

The name caisson is also applied to cylinders of cast iron or

steel, which are sunk by removing the material from the inside either by manual labor or by dredging.

The processes employed to aid the sinking of inverted caissons are called the "vacuum" and the "plenum."

The *vacuum process* consists in exhausting the air from the interior of the caisson, and using the pressure of the atmosphere upon top of it to force it down. Exhausting the air allows the water to flow past the lower edge into the interior, thus loosening the soil.

The *plenum* or *compressed-air process* consists in pumping air into the chamber of the caisson, which by its pressure excludes the water. An air-lock or entrance provided with suitable doors is arranged in the top of the caisson, by which workmen can enter to loosen up the soil and otherwise aid in the sinking of the caisson vertically by removing and loosening the material at the sides. If the loosened material is of a suitable character it is removed with a sand-pump; if not, suitable hoisting apparatus is provided and it is loaded into buckets by the workmen and hoisted out through the air-lock.

COFFER-DAMS are temporary enclosures from which water may be pumped out so as to allow of work being done within them. Their construction varies greatly, depending upon the conditions to be met.

The most perfect form consists of two parallel rows of main and sheet piles enclosing between them a vertical wall of clay puddle. Simple banks of clay and gravel, or of bags filled with clay, or a single row of sheet-piling protected with a bank of clay are used where the conditions permit.

CRIBS.—Timber cribs consist of a series of layers of round or squared timber, laid alternately lengthwise and crosswise, notched and pinned to each other at their intersections, each notch being about one fourth the depth of the stick. The crib forms a series of square or rectangular cells, which are usually filled with stones.

FREEZING PROCESS.—This process is employed in sinking foundation-pits through quicksand and soils saturated with water. The Poetsch-Sooysmith process is to sink a series of pipes 10 inches in diameter through the earth to the rock; these are sunk in a circle around the proposed shaft. Inside of the 10-inch pipes 8-inch pipes closed at the bottom are placed, and inside of these are placed smaller pipes open at the bottom. Each set of the small pipes is connected in a series. A freezing mixture is then allowed to flow downwards through one set of

the smaller pipes and return upwards through the other. The freezing mixture flows from a tank placed at a sufficient height to cause the liquid to flow with the desired velocity through the pipes. The effect of this process is to freeze the earth into a solid wall.

GRILLAGE is a frame of one or more courses of timber, drift-bolted or -pinned to the tops of piles and to each other, upon which a floor of thick planks is placed to receive the bottom courses of masonry.

The timbers which rest upon the piles are called *caps;* they are usually about 1 foot square, and are fastened by boring a hole through each one into the head of the pile and driving into the hole a plain rod or bar of iron having about 25 per cent larger cross-section than the hole.

These rods are called *drift-bolts,* and are usually either a rod 1 inch in diameter (driven into a ¾-inch auger-hole) or a bar 1 inch square (driven into a ⅞-inch hole). Formerly jag-bolts or rag-bolts, i. e., bolts whose sides were jagged or barbed, were used for this and similar purposes, but universal experience shows that smooth rods hold much better. Round bolts are preferable to square, because they do not cut or tear the wood. The ends of the rods should be slightly pointed with a hammer.

Transverse timbers are put on top of the caps and drift-bolted to them. As many courses may be added as is necessary, each perpendicular to the one below it. The timbers of the top course are laid close together, or, as before stated, a floor of thick plank is added on top to receive the masonry.

Grillages formed of iron and steel rails and beams bedded in concrete are being extensively employed for the foundations of steel and iron buildings. The method employed is to cover the bottom of the foundation-pit with a layer of concrete ; on this is placed a layer of steel I beams or rails spaced 6 to 8 inches apart and the spaces between them filled in with concrete. These are covered with a similar set at right angles and concreted, and then again with a third or fourth course, and the whole finished flush with concrete.

Before the beams are laid on the concrete it is recommended that its surface be covered with two thicknesses of tarred felt laid in hot asphalt, and on top of this a layer of cement mortar 1¼ inches thick, in which the beams are bedded.

Before the beams are laid they should be thoroughly cleansed with wire brushes, and while dry either painted with asphalt or

heated and dipped in asphalt. Before covering the beams with the concrete every portion of the metal should be examined, and wherever the coating has been scraped off in handling should be thoroughly dried and recoated or painted.

Piles.—The materials employed for piles are timber, rolled, forged, or cast steel, and wrought-iron pipes and cast-iron cylinders.

TIMBER PILES are generally round, and have a length of about twenty times their mean diameter. The diameter of the butt varies from 9 to 18 inches.

The timber employed for piles varies with the conditions. For soft or medium soils or situations in which the piles will be always under water spruce and hemlock are frequently used. For firmer soils the hard pines, fir, elm, and beech are generally used. For still more compact soils, and where the pile is alternately wet and dry, white or black oak and yellow or Southern pine are used.

Where piles are exposed to tide-water they are generally driven with the bark on. In other cases it is not essential.

In Southern waters special precautions are necessary to protect the piles from the ravages of the *Teredo*. In Florida the palmetto-wood is extensively used on account of its being little attacked by the *Teredo*.

In driving through hard ground the point of the pile is sometimes protected with a shoe of either cast or wrought iron, and the head bound with an iron hoop to prevent splitting.

As a rule, piles drive better when cut off square than when pointed; iron shoes generally strip off before the pile has penetrated far.

Description of Piles.

ANCHOR-PILE: A pile driven at some distance from another, usually at an angle, to which the face-pile is fastened by an iron tie-rod to prevent the face-pile springing or being forced out of its position.

BEARING-PILES are long piles driven into the soil to act as pillars in supporting the load. They may either be driven through the soft stratum until they reach a firm stratum and penetrate a short distance into it, or, if that be impracticable, they may be supported wholly by the friction of the soft stratum.

The load which bearing-piles will carry depends upon the character of the material into which they are driven.

In sand and soft clays piles driven to depths of 40 to 50 ft. will carry safely from 20 to 30 tons per pile. If driven through to rock or hardpan, so that the pile becomes a timber column, they will carry safely 50 to 70 tons per pile. Piles driven into soft, silty, and marshy soils, and penetrating to 60, 80, or even 100 or more feet without reaching firm soil of any kind, may carry safely loads from 10 to 25 tons.

CLOSE PILE: A pile of square timber driven close to another.

DISK-PILE: A bearing-pile near the foot of which a disk is keyed or bolted to give additional bearing power.

FALSE-PILE: An additional length added to a pile after driving.

FENDER PILE: A pile driven to ward off blows from floating bodies.

FILLING-PILES: Piles filling the space between gauge-piles.

FOUNDATION-PILE: One driven to increase the supporting power of the soil under a foundation.

GAUGE-PILES: Piles placed to mark the desired course of a row of piles.

In dredging, piles driven to mark the course and depth of the excavations.

GUIDE-PILES: Piles which limit the field of operations in dredging.

HOLLOW PILES.—Cylinders of cast iron sunk by excavating from the interior. They are cast in various lengths and diameters. Short lengths are usually employed for those of small diameter, sections being added as they sink, the sections being fas-

tened together by internal flanges. When they have reached the stratum upon which they are to rest they are usually filled with concrete. If used to resist sea-water the iron should be close-grained white iron.

IRON AND STEEL PILES.—Both cast and wrought iron and steel are employed for ordinary bearing-piles, sheet-piles, and for cylinders. Iron cylinders are usually sunk either by dredging the soil from the inside or by the pneumatic process.

Cast-iron piles are used as substitutes for wooden ones. Lugs or flanges are usually cast on the sides of the piles, to which bracing may be attached for securing them in position. A wood block is laid upon top of the pile to receive the blows of the hammer used in driving it, and after being driven a cap with a socket in its lower side is placed upon the pile to receive the load.

Solid rolled-steel piles are driven in the same manner as timber piles, either with a hammer, machine, or water-jet.

PNEUMATIC-PILE : A metal cylinder similar to a hollow pile, but sunk by atmospheric pressure.

SAND-PILES : The practical incompressibility of sand renders it an excellent foundation wherever it can be protected from wash by water. The form in which it is most successfully used is that of piles. The ground is prepared by driving timber piles, then withdrawing them and filling the holes with sand.

The sand used should be moderately fine, angular-grained, clean, and uniform in size. If wet it should be rammed with considerable force. If dry it arranges itself better, and when in place may be moistened and rammed.

SCREW-PILES are piles which are screwed into the stratum in which they are to stand. They are ordinary piles of timber or iron (the latter usually hollow), to the bottom of which a screw-disk, consisting of a single turn of the spiral, similar to the bottom turn of an auger, is fastened by bolts or pins; and instead of driving them into the ground they are forced in by turning them with levers or machinery suitable for the purpose. The screw-disks vary in diameter from 1 to 6 feet. The water-jet is sometimes employed by applying it to the under, upper, or both sides of the disk for the purpose of reducing the resistance.

SHEET-PILES are flat piles, usually of plank, either tongued and grooved or grooved only, into which a strip or tongue is driven; or they may be of squared timber, in which case they are called "close piles," or of sheet iron. The timber ones are of any breadth that can be procured, and from 2 to 10 inches thick, and

are sharpened at the lower end to an edge wholly from one side; this point being placed next to the last pile driven tends to crowd them together and make tighter joints (the angle formed at the point should be 30°). In stony ground they are shod with iron.

When a space is to be enclosed with sheet-piling two rows of guide-piles are first driven at regular intervals of from 6 to 10 feet, and to opposite sides of these near the top are notched or bolted a pair of parallel string-pieces or "wales," from 5 to 10 inches square, so fastened to the guide-piles as to leave a space between the wales equal to the thickness of the sheet-piles. If the sheeting is to stand more than 8 or 10 feet above the ground a second pair of wales is required near the level of the ground. The sheet-piles are driven between the wales, working from each end towards the middle of the space between a pair of guide-piles, so that the last or central pile acts as a wedge to tighten the whole.

Sheet-piles are driven either by mauls wielded by men or by a pile-driving machine. Ordinary planks are also used for sheet-piling, being driven with a lap; such piling is designated as "single-lap," "double-lap," and "triple-lap." The latter is also known as the "Wakefield triple-lap sheet-piling."

Short Piles are driven in order to compress and consolidate the soil. They are usually of round timbers, from 6 to 9 inches in diameter and from 6 to 12 feet long, and are driven as close to each other as is practicable without causing the neighboring piles to rise. The centre pile should be driven first, then the next without, and so on to the outside row.

Test-pile: A pile driven to test the character of the soil.

Pile-driving.

Timber piles are driven either point or butt end down; the latter is considered the better method.

When piles are directed to be sharpened the points should have a length of from one and a half times to twice the diameter.

To prevent the head of the pile from being broomed or split by the blows of the driving-ram it is bound with a wrought-iron hoop, 2 to 3 inches wide and ½ to 1 inch thick. Instead of the wrought-iron band a cast-iron cap is sometimes used. It consists of a block with a tapering recess above and below, the chamfered head of the pile fitting into the one below, and a cushion-piece of hard wood upon which the hammer falls fitting into the one above.

When brooming occurs the broomed part should be cut off, because a broomed head cushions the blow and dissipates it without any useful effect.

Piles that split or broom excessively or are otherwise injured during the driving must be drawn out.

Bouncing of the hammer occurs when the pile refuses to drive further, or it may be caused by the hammer being too light, or its striking velocity being too great, or both. The remedy for bouncing is to diminish the fall. A slight bounce should occur at the end of every blow.

Excessive hammering on piles which refuse to move should be avoided, as they are liable to be crippled, split, or broken below the ground, which will pass unnoticed and may be the cause of future failure.

As a general rule, a heavy hammer with a low fall drives more pleasantly than a light one with a high fall. More blows can be made in the same time with a low fall, and this gives less time for the soil to compact itself around the piles between the blows. At times a pile may resist the hammer after sinking some distance, but start again after a short rest; or it may refuse a heavy hammer and start under a light one. It may drive slowly at first, and more rapidly afterwards, from causes that may be difficult to discover. The driving of one sometimes causes adjacent ones previously driven, to spring upwards several feet. The driving of piles in soft ground or mud will generally cause an adjacent one previously driven to lean outwards unless means be taken to prevent it.

A pile may rest upon rock and yet be very weak, for if driven

through very soft soil all the pressure is borne by the sharp point, and the pile becomes merely a column in a worse condition than a pillar with one rounded end. In such soils the piles need very little sharpening; indeed, had better be driven without any, and better butt end down.

Solid metal piles are usually of uniform diameter and are driven with either blunt or sharpened points.

Piles are driven by machines called *pile-drivers*. They consist essentially of two upright guides or leads, often of great height. erected upon a platform, or on a barge when used in water These guides serve to hold the pile vertical while being driven, and also hold and guide the hammer used in driving. This is a block of iron called a ram, monkey, or hammer, weighing any where from 800 to 4000 pounds; average weight. from 2000 to 3000 pounds. The accessories are a hoisting-engine for raising the hammer and the devices for allowing it to drop freely on the heads of the piles.

The steam-hammer is also employed for driving piles, and has certain advantages over the ordinary form, the chief of which lies in the great rapidity with which the blows follow one another, allowing no time for the disturbed earth, sand, etc., to recompact itself around the sides and under the foot of the pile. It is less liable than others to split and broom the piles, so that these may be of softer and cheaper wood. The piles are not so liable to "dodge" or "get out of line."

When piles have to be driven below the end of the leaders of the pile-driver a *follower* is used. This is made from a pile of suitable length placed on top of the pile to be driven; to prevent its bouncing off caps of cast iron are used, one end being bolted to the follower and the other end fitting over the head of the pile.

Piles are also driven by the "water-jet." This process consists of an iron pipe fastened by staples to the side of the pile, its lower end placed near the point of the pile and its upper end connected by a hose to a force-pump. The pile can be sunk through almost any material, except hardpan and rock, by forcing water through the pipe. It seems to make very little difference, either in the rapidity of sinking or in the accuracy with which the pile preserves its position, whether the nozzle is exactly under the middle of the pile or not.

The efficiency of the jet depends upon the increased fluidity given the material into which the piles are sunk, the actual dis-

placement of material being small Hence the efficiency of the jet is greatest in clear sand, mud. or soft clay, in gravel or in sand containing a large percentage of gravel, or in hard clay the jet is almost useless. For these reasons the engine pump hose and nozzle should be arranged to deliver large quantities of water with a moderate force rather than smaller quantities with high initial velocity. In gravel or in sand containing gravel some benefit might result from a velocity sufficient to displace the pebbles and drive them from the vicinity of the pile.

The error most frequently made in the application of the water-jet is in using pumps with insufficient capacity.

The approximate volume of water required per minute per inch of average diameter of pile for penetrations under 40 feet is 16 gallons, for greater depths the increase in the volume of water is approximately at the rate of 4 gallons per inch of diameter of pile per minute for each additional 10 feet of penetration.

The number and size of pipes required for various depths are about as follows;

Depth of Penetration Feet.	Diameter of Pipe. Inches.	Number of Pipes.	Diameter of Nozzle Inches.
20	2	1	1
30	2½	1	1¼
40	2½	2	1⅛
50	2½	2	1
60	2½	2	⅞

When the descent of the pile becomes slow, or it sticks or "brings up" in some tenacious material, it can usually be started by striking a few blows with the pile-driving hammer, or by raising the pile about 6 inches and allowing it to drop suddenly, with the jet in operation. By repeating the operation as rapidly as possible the obstruction will generally be overcome.

It is an advantage to use an ordinary pile-driving machine for sinking piles with the water-jet The hammer being allowed to rest upon the head of the pile aids in accelerating the descent, and light blows can be struck as often as may appear necessary. The efficiency of the jet can also be greatly increased by bringing the weight of the pontoon upon which the machinery is placed to bear upon the pile by means of a block and tackle.

SPLICING PILES —It frequently happens in driving piles in swampy places, for false works, etc., that a single pile is not long enough, in which case two are spliced together A common method of doing this is as follows. After the first pile is driven its head is cut off square, a hole 2 inches in diameter and 12 inches deep is bored in its head, and an oak treenail or dowel-pin 23 inches long is driven into the hole; another pile similarly squared and bored is placed upon the lower pile, and the driving continued. Spliced in this way the pile is deficient in lateral stiffness, and the upper section is liable to bounce off while driving. It is better to reinforce the splice by flattening the sides of the piles and nailing on with, say, 8 inch spike four or more pieces 2 or 3 inches thick, 4 or 5 inches wide, and 4 to 6 feet long.

Inspection of Piles.

As soon as the piles are delivered on the work they must be carefully examined, both as regards dimensions and quality, and those failing to meet the specification requirements must be conspicuously marked with paint or burning-iron to indicate that they are condemned. All condemned piles must be removed as speedily as possible; otherwise many of them are liable to find their way into the work.

Round piles should be made from live timber, free from cracks, wind-shakes, and large knots. They should be so straight that a straight line taken in any direction from the centre of each end of the pile and run the length of it shall show that the pile is at no point over one eighth of its diameter at such point out of a straight line.

It is very necessary that the inspector watch the driving of every pile, for there is some danger that piles shorter than required may be introduced into the work, or that workmen, to save themselves trouble or for other reasons, may drive a pile only a portion of the required distance, and then cut it off.

In cutting off the heads of piles they must be sawn level. Usually, however, they are sawn so that the heads are either concave or inclined. Both cases are due to the manner of holding the saw. Such defects are not permissible, and pile-heads so cut must be recut in the proper manner.

Piles frequently get considerably out of line in driving. In some cases they may be forced back with a block and tackle or a jack screw.

The inspector is usually required to keep a record of the pile-driving. The following form will be found convenient:

PILE-DRIVING RECORD.

	Pile Number.						
	1	2	3	4	5	6	7
Date							
Kind of timber							
Length							
Diameter butt							
" point							
Length driven							
" cut off							
Weight of hammer							
Fall							
No. of blows							
Penetration, 10 blows							
" 20 "							
" 30 "							
" 40 "							
" last blow							
Driven with follower							
Weight of "							
Driven point down							
" butt "							

Clay Puddle.

Clay puddle is a mass of clay and sand worked into a plastic condition with water. It is used for filling coffer-dams, for making embankments and reservoirs water-tight, and for protecting masonry against the penetration of water from behind.

QUALITY OF CLAY.—The clays best suited for puddle are opaque, and not crystallized, should exhibit a dull earthy fracture, exhale when breathed upon a peculiar faint odor termed "argillaceous," should be unctuous to the touch, free from gritty matter, and form a plastic paste with water.

The important properties of clay for making good puddle are its tenacity or cohesion and its power of retaining water. The tenacity of a clay may be tested by working up a small quantity with water into a thoroughly plastic condition, and forming it by hand into a roll about 1 to $1\frac{1}{8}$ inches in diameter by 10 or 12 inches in

length. If such a roll is sufficiently cohesive not to break on being suspended by one end while wet the tenacity of the material is ample.

To test its power of retaining water one to two cubic yards should be worked with water to a compact homogeneous plastic condition, and then a hollow should be formed in the centre of the mass capable of holding four or five gallons of water. After filling the hollow with water it should be covered over to prevent evaporation and left for about 24 hours, when its capability of holding water will be indicated by the presence or absence of water in the hollow.

The clay should be freed from large stones and vegetable matter, and just sufficient sand and water added to make a homogeneous mass. If there is too little sand the puddle will crack by shrinkage in drying, and if too much it will be permeable.

PUDDLING.—The operation of puddling consists in chopping the clay in layers of about 3 inches thick with spades aided by the addition of sufficient water to reduce it to a pasty condition. After each chop and before withdrawing the spade it should be given a lunging motion so as to permit the water to pass through.

The spade should pass through the upper layer into the lower layer so as to cause the layers to bond together.

The test for thorough puddling is that the spade will pass through the layer with ease, which it will not do if there are any dry hard lumps.

Sometimes in place of spades harrows are used, each layer of clay being thoroughly harrowed aided by water and then rolled with a grooved roller to compact it.

The finished puddle should not be exposed to the drying action of the air, but should be covered with a layer of dry clay or sand.

Concrete.

Concrete is a species of artificial stone composed of (1) the matrix, which may be either lime or cement mortar, usually the latter, and (2) the aggregate, which may be any hard material, as gravel, shingle, broken stone, shells, brick, slag, etc.

The essential quality of concrete seems to be that the material of the aggregate should be of small dimensions, so that the cementing medium may act in every direction round them, and that the latter should on no account be more in quantity than is necessary for that purpose. The aggregate should be of different sizes, so that the smaller shall fit into the voids between the larger. This requires less mortar and with good aggregate gives a stronger concrete. Broken stone is the most common aggregate.

To insure compact packing the aggregate should consist of a mixture of broken stone ranging from 1 to 3 inches, and pebbles which are at least equal to the strength of the mortar. Sun-dried or rain-soaked material must be strictly avoided. Gravel and shingle should be screened to remove the larger-sized pebbles, dirt, and vegetable matter, and should be washed if they contain silt or loam. The broken stone if mixed with dust or dirt must be washed before use.

Strength of Concrete.—The resistance of concrete to crushing ranges from about 600 to 1400 pounds per sq. in. It depends upon the kind and amount of cement and upon the kind, size, and strength of the aggregate. The transverse strength ranges between 50 and 400 pounds.

Weight of Concrete.—A cubic yard weighs from 2500 to 3000 pounds according to its composition.

Proportions of Materials for Concrete.

To manufacture one cubic yard of concrete the following quantities of materials are required :

Broken-stone-and-gravel Concrete.

Broken-stone 50% of its bulk voids...	1 cubic yard
Gravel to fill voids in the stone...........	½ " "
Sand to fill voids in the gravel............	¼ " "
Cement to fill voids in the sand..........	⅛ " "

Broken-stone Concrete.

Broken stone 50% of its bulk voids........	1 cubic yard
Sand to fill voids in the stone..............	½ " "
Cement to fill voids in the sand...........	¼ " "

Gravel Concrete.

Gravel ⅓ of its bulk voids...................	1 cubic yard
Sand to fill voids in the gravel............	⅓ " "
Cement to fill voids in the sand............	⅙ " "

Concrete composed of 1 part Rosendale cement, 2 parts of sand, and 5 parts of broken stone requires :

Broken stone..........................	0.92 cubic yard
Sand..................................	0.37 " "
Cement................................	1.43 barrels

The usual proportions of the materials in concrete are :

Rosendale Cement Concrete.

Rosendale cement................................	1 part
Sand..	2 parts
Broken stone................................	3 to 4 "

Portland Cement Concrete.

Portland cement................................	1 part
Sand..	2 to 3 parts
Broken stone or gravel........	3 to 7 "

To make 100 cubic feet of concrete of the proportions 1 to 6 will require 5 bbls. cement (original package) and 4.4 yards of stone and sand.

One barrel of Portland cement, 2 bbls. sand, and 5 bbls. of broken stone will make about 20 cubic feet of concrete; these eight volumes will on setting fill a space of about 5.2 volumes.

Mixing Concrete.—The concrete may be mixed by hand or machinery. In hand-mixing the cement and sand are mixed dry. About half the sand to be used in a batch of concrete is spread evenly over the mortar-board, then the dry cement is spread evenly over the sand, and then the remainder of the sand is spread on top of the cement. The sand and cement are then mixed with a hoe or by turning and re-turning with a shovel. It is very important that the sand and cement be thoroughly mixed. A basin is then formed by drawing the mixed sand and cement to the outer edges of the board, and the whole amount of water required is poured into it. The sand and cement are then thrown back upon the water and thoroughly mixed with the hoe or shovel into a stiff mortar and then levelled off. The broken stone or gravel should be sprinkled with sufficient water to remove all dust and thoroughly wet the entire surface. The amount of water required for this purpose will vary considerably with the absorbent power of the stone and the temperature of the air. The wet stone is then spread evenly over the top of the mortar and the whole mass thoroughly mixed by turning over with the shovel. Two, three, or more turnings may be necessary. It should be turned until every stone is coated with mortar, and the entire mass presents the uniform color of the cement, and the mortar and stones are uniformly distributed. When the aggregate consists of broken brick or other porous material it should be thoroughly wetted and time allowed for absorption previous to use; otherwise it will take away part of the water necessary to effect the setting of the cement.

When the concrete is ready for use it should be quite coherent and capable of standing at a steep slope without the water running from it.

The rules and the practice governing the mixing of concrete vary as widely as the proportion of the ingredients. It may be stated in general that if too much time is not consumed in mixing the wet materials a good result can be obtained by any of the many ways practised, if only the mixing is thorough. With four men the time required for mixing one cubic yard is about ten minutes.

Whatever the method adopted for mixing the concrete, it is advisable for the inspector to be constantly present during the

operation, as the temptation to economize on the cement and to add an excess of water to lighten the labor of mixing is very great.

Laying Concrete.—Concrete is usually deposited in layers, the thickness of which is generally stated in the specifications for the particular work (the thickness varies between 6 and 12 in.) The concrete must be carefully deposited in place. A very common practice is to tip it from a height of several feet into the trench. This process is objected to by the best authorities on the ground that the heavy and light portions separate while falling, and that the concrete is, therefore, not uniform throughout its mass.

The best method is to wheel the concrete in barrows, immediately after mixing, to the place where it is to be laid, gently tipping or sliding it into position and at once ramming it.

The ramming should be done before the cement begins to set, and should be continued until the water begins to ooze out upon the upper surface. When this occurs it indicates a sufficient degree of compactness. A gelatinous or quicksand condition of the mass indicates that too much water was used in mixing. Too severe or long continued pounding injures the strength by forcing the stones to the bottom of the layers and by disturbing the incipient "set" of the cement The ramming in one spot or locality should occupy not less than three minutes and not more than five.

The rammers need not be very heavy 10 to 15 lbs. will be sufficient. Square ones should measure from 6 to 8 in on a side and round ones from 8 to 12 in in diameter

After each layer has been rammed it should be allowed sufficient time to "set," without walking on it or in other ways disturbing it. If successive layers are to be laid the surface of the one already set should be swept clean, wetted. and made rough by means of a pick for the reception of the next layer.

Great care should be observed in joining the work of one day to that of the next. The last layer should be thoroughly compacted and left with a slight excess of mortar. It should be finished with a level surface and when partially set should be scratched with a pointed stick and covered with planks canvas, or straw. In the morning, immediately before the application of the next layer, the surface should be swept clean, moistened with water, and painted with a wash of neat cement mixed with water to the consistency of cream This should be put on in

excess and brushed thoroughly back and forth upon the surface so as to insure a close contact therewith.

Depositing Concrete under Water.—In laying concrete under water an essential requisite is that the materials shall not fall from any height through the water, but be deposited in the allotted place in a compact mass; otherwise the cement will be separated from the other ingredients and the strength of the work be seriously impaired. If the concrete is allowed to fall through the water its ingredients will be deposited in a series, the heaviest—the stone, at the bottom, and the lightest—the cement, at the top. A fall of even one foot causes an appreciable separation.

A common method of depositing concrete under water is to place it in a V shaped box of wood or plate iron, which is lowered to the bottom with a crane. The box is so constructed that on reaching the bottom a latch operated by a rope reaching to the surface can be drawn out, thus permitting one of the sloping sides to swing open and allow the concrete to fall out. The box is then raised and refilled.

A long box or tube, called a *tremie*, is also used. It consists of a tube open at top and bottom built in detachable sections, so that the length may be adjusted to the depth of water. The tube is suspended from a crane or movable frame running on a track, by which it is moved about as the work progresses. The upper end is hopper shaped, and is kept above the water; the lower end rests on the bottom. The tremie is filled in the beginning by placing the lower end in a box with a movable bottom, filling the tube, lowering all to the bottom, and then detaching the bottom of the box. The tube is kept full of concrete by more being thrown in at the top as the mass issues from the bottom.

Concrete is also successfully deposited under water by enclosing it in paper bags and lowering or sliding them down a chute into place. The bags get wet and the pressure of the concrete soon bursts them, thus allowing the concrete to unite into a solid mass. Concrete is also sometimes deposited under water by enclosing it in open-cloth bags, the cement oozing through the meshes sufficiently to unite the whole into a single mass.

Concrete should not be deposited in running water unless protected by one or other of the above-described methods; otherwise the cement will be washed out.

Concrete deposited under water should not be rammed, but if

necessary may be levelled with a rake or other suitable tool immediately after being deposited

When concrete is deposited in water a pulpy, gelatinous fluid is washed from the cement and rises to the surface. This causes the water to assume a milky hue. The French engineers apply the term *laitance* to this substance. It is more abundant in salt water than in fresh. The theory of its formation is that the immersed concrete gives up to the water. free caustic lime, which precipitates magnesia in a light and spongy form. This precipitate sets very slowly, and sometimes scarcely at all, and its interposition between the layers of concrete forms strata of separation. The proportion of laitance is greatly diminished by using large immersion-boxes, or a tremie, or paper or cloth bags.

Asphaltic Concrete is composed of asphaltic mortar and broken stone in the proportion of 5 parts of stone to 3 parts of mortar. The stone is heated to a temperature of about 250° F and added to the hot mortar The mixing is usually performed in a mechanical mixer.

The material is laid hot and rammed until the surface is smooth. Care is required that the materials are properly heated, that the place where it is to be laid is absolutely dry and that the ramming is done before it chills or becomes set. The rammers should be heated in a portable fire.

III. MASONRY.

Classification of Masonry.

Masonry is classified according to the nature of the material used, as "stone masonry," "brick masonry," and "mixed masonry," composed of stones and bricks.

Stone masonry is classified (1) according to the manner in which the material is prepared, as: "rubble masonry," "squared-stone masonry," "ashlar masonry," "broken ashlar," and the combinations of these four kinds; and (2) according to the manner in which the work is executed, as: "uncoursed rubble," "coursed rubble," "dry rubble," "regular-coursed ashlar," "broken- or irregular-coursed ashlar," "ranged work," "random ranged," etc.

Preparation of the Stones

CLASSIFICATION OF THE STONES.

All the stones used in building are divided into three classes according to the finish of the surface, viz.: 1. Rough stones that are used as they come from the quarry. 2. Stones roughly squared and dressed. 3. Stones accurately squared and finely dressed.

UNSQUARED STONES.—This class covers all stones which are used as they come from the quarry without other preparation than the removal of very acute angles and excessive projections from the general figure.

SQUARED STONES.—This class covers all stones that are roughly squared and roughly dressed on beds and joints. The dressing is usually done with the face-hammer or -axe, or in soft stones with the tooth hammer. In gneiss, hard limestones, etc., it may be necessary to use the point. The distinction between this class and the third lies in the degree of closeness of the joints. Where the dressing on the joints is such that the distance between the general planes of the surfaces of adjoining stones is one half inch or more the stones properly belong to this class.

Three subdivisions of this class may be made, depending on the character of the face of the stones.

(*a*) QUARRY-FACED or ROCK-FACED stones are those whose faces are left untouched as they come from the quarry.

(*b*) PITCHED-FACED stones are those on which the arris is clearly defined by a line beyond which the rock is cut away by the pitching-chisel, so as to give edges that are approximately true.

(*c*) DRAFTED STONES are those on which the face is surrounded by a chisel-draft, the space inside the draft being left rough. Ordinarily, however, this is done only on stones in which the cutting of the joints is such as to exclude them from this class.

In ordering stones of this class the specifications should always state the width of the bed and end joints which are expected, and also how far the surface of the face may project beyond the plane of the edge. In practice the projection varies between 1 inch and 6 inches. It should also be specified whether or not the faces are to be drafted.

CUT STONES.—This class covers all squared stones with smoothly dressed beds and joints. As a rule, all the edges of cut stones are drafted, and between the drafts the stone is smoothly dressed. The face, however, is often left rough where construction is massive. The stones of this class are frequently termed "dimension" stone or "dimension" work.

Stone-cutting.

DRESSING THE STONES.—The stone-cutter examines the rough blocks as they come from the quarry in order to determine whether the block will work to better advantage as a header, a stretcher, or a corner-stone. Having decided for which purpose the stone is suited, he prepares to dress the bottom bed. The stone is placed with the bottom bed up, all the rough projections are removed with the hammer and pitching-tool, and approximately straight lines are pitched off around its edges; then a chisel-draft is cut on all the edges. These drafts are brought to the same plane as nearly as practicable by the use of two straight-edges having parallel sides and equal widths, and the enclosed rough portion is then dressed down with the pitching-tool or point to the plane of the drafts. The entire bed is then pointed down to a surface true to the straight-edge when applied in any direction—crosswise, lengthwise, and diagonally.

Lines are then marked on this dressed surface parallel and perpendicular to the face of the stone, enclosing as large a rectangle as the stone will admit of being worked to, or of such dimensions as may be directed by the plan.

The faces and sides are pitched off to these lines. A chisel-draft is then cut along all four edges of the face, and the face either dressed as required or left rock-faced. The sides are then pointed down to true surfaces at right angles to the bed. The stone is turned over bottom bed down, and the top bed dressed in the same manner as the bottom. It is important that the top bed be exactly parallel to the bottom bed in order that the stone may be of uniform thickness.

Stones having the beds inclined to each other, as skew-backs, or stones having the sides inclined to the beds, are dressed by using a bevelled straight-edge set to the required inclination.

Arch-stones have two plane surfaces inclined to each other; these are called the beds. The upper surface or extrados is usually left rough; the lower surface or intrados is cut to the curve of the arch. This surface and the beds are cut true by the use of a wooden or metal templet which is made according to the drawings furnished by the engineer or architect.

Dressing Granite.

The tools employed in dressing granite are the set, the spalling-hammer, the pean-hammer, the bush-hammer, the chisel, the bush-chisel, the point, and the hand-hammer. The set is used for dressing the edges of a block to a line. The spalling-hammer is sometimes used for taking off larger projections than can be dressed off with the set, but such projections are commonly taken off with wedges (or "plugged off"). The point is used for roughing out the contour of surfaces. With the pean-hammer the projections left by the point are cut down. The bush-hammer imparts a finish according to the number of cuts employed. The chisel is used for finishing mouldings, for cutting drafts around rock-faced and pointed work, and for lettering and tracing. The bush-chisel is used for dressing portions of surfaces not accessible with the bush-hammer. The set, point, and chisels are driven with the hand-hammer.

The steps in the process of dressing a granite surface are: 1st, dressing the edges to a line with the set; 2d, roughing out the surface with the point; 3d, cutting down the irregularities left

by the point with the pean-hammer; and 4th, dressing down with the 4-cut, 6-cut, 8-cut, 10-cut, and 12-cut bush-hammers successively the irregularities left by each preceding tool.

This process is carried out to different degrees for the different kinds of finished dressing, known as rock-faced work, pointed work, single-cut or pean-hammered work, and 4-cut, 6-cut, 8-cut, 10-cut, and 12-cut work. For pointed work there is usually a draft chiselled around the face, after which the space within is dressed to a level with the draft or is given a certain projection, and may be rough-pointed or fine-pointed. Rock-faced work is sometimes drafted. The bed and joint surfaces are dressed to a degree of fineness depending upon the closeness of the joint requried.

The condition of the surface at the completion of any particular cut work should be such that each cut in the hammer traces a line its full length on the stone at every blow. The first cut should leave no unevenness exceeding one eighth of an inch, and each finer cut reduces the amount of unevenness; and the 12-cut should leave no irregularities other than the indentations made by the impinging of the blades in the hammer upon the surface of the stone. The lines of the cuts are made to be vertical on exposed faces; on the beds and unexposed surfaces they are made straight across in the direction which is most convenient.

For fine and accurate work all the tools designated in the complete process are used, except that a 5-cut hammer is often substituted for the 4-cut and the 6-cut hammers; but some of the tools are ordinarily omitted, the 6-cut being made to follow the pean-hammer, the 10-cut to follow the 6-cut, etc.

Sawing and cutting granite by machinery is used, but not extensively.

POLISHING GRANITE.—The surface of granite for polishing is prepared with the 10-cut or the 12-cut bush-hammer. The process of polishing consists in: 1st, rubbing with sand; 2d, with emery; and 3d, with putty-powder. All these polishing materials are put on with just sufficient water to make a paste which is not gummy. The putty-powder is rubbed on with a felt-covered block to give the surface a gloss finish. The machine employed for polishing is iron wheels formed of several concentric rings.

Dressing Sandstone.

The steps in the process of cutting sandstone are similar to those in the process of cutting marble, except that the crandall takes the place of the tooth-chisel on large surfaces. The diamond-hammer is used after the crandall on some kinds of sandstone, and the bush-hammer is used on hard, compact, argillaceous sandstones like the North River bluestone.

Blocks of sandstone are sawed with gang-saws. Some sandstones are so soft when first taken from the quarry that they can be sawed without the aid of sand.

A rubbed surface is the finest finish of which sandstone is susceptible. The surface may be rubbed with sand alone, or with sand followed by grit.

Slabs of North River bluestone are planed, like slabs of slate, before they are rubbed.

Dressing Limestone.

The beds of limestone are usually smooth enough to be used in ordinary masonry without dressing. The ends are jointed with the pitching-tool and point, and the faces are commonly dressed rock-face. Heavily bedded limestones are commonly sawed with gang-saws, and the various kinds of finish given the faces are rock-face, pointed, tooled, drove, or rubbed. Sometimes the tooth-axe is used after the point, after that the axe-hammer, and then the diamond-hammer.

Dressing Marble.

The steps taken in the process of cutting marble are: 1st, shaping up the block with the spalling-hammer and pitching-tool; 2d, roughing out the surface with the point; 3d, cutting down the projection left by the point with the tooth-chisel; and 4th, cutting the surface smooth with the drove.

The spalling-hammer is used for breaking off the larger projections, and the pitching-tool is used for dressing the edges to a line. Chisels having a bit more than one inch in width are called "droves"; smaller sizes are called "tools."

A finished surface is usually drove, tooled, or polished. Rock-faced, pointed, and tooth-chiselled work is seldom employed. A

tooled surface is made with the chisel, and has a ridged or wavy appearance, due to the lines of indentations made by the tool. Machines are extensively employed for working marble.

POLISHING MARBLE.—Surfaces to be polished are finished with the "drove." The steps involved in the process of polishing are: 1st, rubbing with coarse sand; 2d, with finer sand; 3d, with coarse grit; 4th, with finer grit; 5th, with pumice-stone; 6th, polishing with Scotch bone; and 7th, glossing with putty-powder, with sometimes the addition of oxalic acid. Water is applied in every step of the process.

It is usually specified in contracts for polished work that no oxalic acid shall be used, because a more durable polish is obtained by the use of putty-powder alone.

Small blocks are rubbed with sand on the rubbing-bed; otherwise machines similar to those used for polishing granite are used for applying the sand and putty-powder. The grit consists of spalls from a sand-rock which has a texture suitable for grindstones. The grit and pumice-stone and Scotch bone are applied by hand. Each step in the process must eradicate all traces of the preceding step. All scratches must be removed from the surface before beginning the work of imparting the gloss finish.

A dressed surface of most colored marbles will have cavities, which must be filled before the marble is polished. This filling is done with a wax made of shellac and colored with any non-oily substance; it is applied with a red-hot strip of iron, and before the wax cools a little of the marble-dust is rubbed into it. The same material is also used for cementing pieces of colored marble together. White marble cannot be successfully filled.

Dressing Slate.

Roofing-slate is prepared by splitting the blocks of slate as they come from the quarry. The splitter uses a broad, thin chisel. He splits the block of slate through the middle, and continues to divide the pieces into equal halves until they are reduced to the required thinness. The edges of the block must be kept moist from the time the rock is taken from the quarry until it is split up. In some quarries the blocks split best from the side, and in others from the end; and in some qualities of slate the splitting-chisel may be driven in its whole length without danger of breaking the slate, while in others it is neces-

sary to lead the split by driving the chisel slightly all around the edges of the block before driving it in at any one point. There are many other little peculiarities which need to be watched by the splitter, and almost every different quarry presents some characteristic features which modify the working of the slate.

To trim slate by hand a straight-edged strip of iron or steel is fastened horizontally on one of the upper edges of a rectangular block about 18 inches in height; the trimmer lays the slate upon the block, allowing one of the irregular edges to project over the iron plate, and cutting it off by a chopping stroke with a heavy knife. In this manner he trims two edges at right angles to each other, and then marks out the other two edges with a measuring-stick before trimming them. The measuring-stick has a nail through one end and notches or steps toward the other end at distances from the point of the nail corresponding with the lengths and breadths of slates made.

Machines operated by manual power are also used for trimming slates.

For mantels, lavatories, and many other purposes slate is worked up principally by machinery. The blocks are taken from the quarries to the slate-mills and there split into slabs about 2 inches in thickness and sawed into the required sizes with circular saws. The sawed slabs are planed with a planing-machine like the machines used for planing iron. The planer-chisels vary in width from 2 to 6 inches, according to the softness of the slate. The slabs are finished by rubbing with sand and water. The rubbing-bed is a flat, circular piece of cast iron, from 8 to 10 feet in diameter, revolving horizontally on a shaft.

Slates do not receive a gloss polish, but if a finer surface is desired than that which can be given by the rubbing-bed it is rubbed by hand with fine sand or emery.

Methods of Finishing the Faces of Cut Stone.

In architecture there are a great many ways in which the faces of cut stone may be dressed, but the following are those that will be usually met in engineering work.

ROUGH-POINTED.—When it is necessary to remove an inch or more from the face of a stone it is done by the pick or heavy point until the projections vary from $\frac{1}{2}$ to 1 inch. The stone is said to be rough-pointed. In dressing limestone and granite this operation precedes all others.

FINE-POINTED.—If a smoother finish is desired rough-pointing is followed by fine-pointing, which is done with a fine point. Fine-pointing is used only where the finish made by it is to be final, and never as a preparation for a final finish by another tool.

CRANDALLED.—This is only a speedy method of pointing, the effect being the same as fine-pointing, except that the dots on the stone are more regular. The variations of level are about $\frac{1}{8}$ inch and the rows are made parallel. When other rows at right angles to the first are introduced the stone is said to be *cross-crandalled.*

AXED OR PEAN-HAMMERED, AND PATENT-HAMMERED.—These two vary only in the degree of smoothness of the surface which is produced. The number of blades in a patent hammer varies from 6 to 12 to the inch; and in precise specifications the number of cuts to the inch must be stated, such as 6-cut, 8-cut, 10-cut, 12-cut. The effect of axing is to cover the surface with chisel-marks, which are made parallel as far as practicable. Axing is a final finish.

TOOTH-AXED.—The tooth-axe is practically a number of points, and it leaves the surface of a stone in the same condition as fine-pointing. It is usually, however, only a preparation for bush-hammering, and the work is then done without regard to effect, so long as the surface of the stone is sufficiently levelled.

BUSH-HAMMERED.—The roughnesses of a stone are pounded off by the bush-hammer, and the stone is then said to be "bushed." This kind of finish is dangerous on sandstone, as experience has shown that sandstone thus treated is very apt to scale. In dressing limestone which is to have a bush-hammered finish the usual sequence of operation is (1) rough-pointing, (2) tooth-axing, and (3) bush-hammering.

RUBBED.—In dressing sandstone and marble it is very common to give the stone a plane surface at once by use of the stone-saw. Any roughnesses left by the saw are removed by rubbing with grit or sandstone. Such stones, therefore, have no margins. They are frequently used in architecture for string-courses, lintels, door-jambs, etc.; and they are also well adapted for use in facing the walls of lock-chambers and in other positions where a stone surface is liable to be rubbed by vessels or other moving bodies.

DIAMOND PANELS.—Sometimes the space between the margins is sunk immediately adjoining them, and then rises gradually until the four planes form an apex at the middle of the panel. In general such panels are called diamond panels, and the form just described is called a sunk diamond panel. When the surface of the stone rises gradually from the inner lines of the margins to the middle of the panel it is called a raised diamond panel. Both kinds of finish are common on bridge-quoins and similar work.

Tools used in Stone-cutting.

The DOUBLE-FACE HAMMER is a heavy tool, weighing from 20 to 30 pounds, used for roughly shaping stones as they come from the quarry and for knocking off projections. This is used for only the roughest work.

The FACE-HAMMER has one blunt and one cutting end, and is used for the same purpose as the double-face hammer where less weight is required. The cutting end is used for roughly squaring stones preparatory to the use of finer tools.

The CAVIL has one blunt and one pyramidal or pointed end, and weighs from 15 to 20 pounds. It is used in quarries for roughly shaping stone for transportation.

The PICK somewhat resembles the pick used in digging, and is used for rough-dressing, mostly on limestone and sandstone. Its length varies from 15 to 24 inches, the thickness at the eye being about 2 inches.

The AXE or PEAN-HAMMER has two opposite cutting edges. It is used for making drafts around the arris or edge of stones, and in reducing faces, and sometimes joints, to a level. Its length is about 10 inches and the cutting edge about 4 inches. It is used after the point and before the patent hammer.

The TOOTH-AXE is like the axe, except that its cutting edges are divided into teeth, the number of which varies with the kind of

work required. This tool is not used in granite- and gneiss-cutting.

The BUSH-HAMMER is a square prism of steel, whose ends are cut into a number of pyramidal points. The length of the hammer is from 4 to 8 inches and the cutting face from 2 to 4 inches square. The points vary in number and in size with the work to be done. One end is sometimes made with a cutting edge like that of the axe.

The CRANDALL is a malleable-iron bar about 2 feet long slightly flattened at one end. In this end is a slot 3 inches long and $\frac{3}{8}$ inch wide. Through this slot are passed ten double-headed points of $\frac{1}{4}$-inch square steel 9 inches long, which are held in place by a key.

The PATENT HAMMER is a double-headed tool so formed as to hold at each end a set of wide thin chisels. The tool is in two parts, which are held together by the bolts which hold the chisels. Lateral motion is prevented by four guards on one of the pieces. The tool without the teeth is $5\frac{1}{2} \times 2\frac{3}{4} \times 1\frac{1}{2}$ inches. The teeth are $2\frac{3}{4}$ inches wide; their thickness varies from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch. This tool is used for giving a finish to the surface of stones.

The HAND-HAMMER, weighing from 2 to 5 pounds, is used in drilling holes and in pointing and chiselling the harder rocks.

The MALLET is used where the softer limestones and sandstones are cut.

The PITCHING-CHISEL is usually of $1\frac{1}{8}$-inch octagonal steel, spread on the cutting edge to a rectangle of $\frac{1}{8} \times 2\frac{1}{2}$ inches. It is used to make a well-defined edge to the face of a stone, a line being marked on the joint surface, to which the chisel is applied and the portion of the stone outside of the line broken off by a blow with the hand-hammer on the head of the chisel.

The POINT is made of round or octagonal steel from $\frac{1}{4}$ to 1 inch in diameter. It is made about 12 inches long, with one end brought to a point. It is used until its length is reduced to about 5 inches. It is employed for dressing off the irregular surface of stones, either for a permanent finish or preparatory to the use of the axe. According to the hardness of the stone, either the hand-hammer or the mallet is used with it.

The CHISEL is of round steel of $\frac{1}{4}$ to $\frac{3}{4}$ inch diameter and about 10 inches long, with one end brought to a cutting edge from $\frac{1}{4}$ inch to 2 inches wide; is used for cutting drafts or margins on the face of stones.

The TOOTH-CHISEL is the same as the chisel except that the cutting edge is divided into teeth. It is used only on marbles and sandstones.

The SPLITTING-CHISEL is used chiefly on the softer stratified stones, and sometimes on fine architectural carvings in granite.

The PLUG, a truncated wedge of steel, and the *feathers* of half-round malleable iron, are used for splitting unstratified stone. A row of holes is made with the *drill* on the line on which the fracture is to be made; in each of these holes two feathers are inserted, and the plugs lightly driven in between them. The plugs are then gradually driven home by light blows of the hand-hammer on each in succession until the stone splits.

MACHINE-TOOLS.—In all large stone-yards machines are used to prepare the stone. There is a great variety in their form, but since the kind of dressing never takes its name from the machine which forms it, it will be neither necessary nor profitable to attempt a description of individual machines. They include stone-saws, stone-cutters, stone-planers, stone-grinders, stone-polishers, etc.

Definition of Terms used in Stone-cutting.

AXED : Dressed to a plane surface with an axe.

BOASTED or CHISELLED : Having face wrought with a chisel or narrow tool.

BROACHED : Dressed with a "punch" after being droved.

BUSH-HAMMERED : Dressed with a bush-hammer.

CRANDALLED : Wrought to a plane with a crandall.

DEADENING : The crushing or crumbling of a soft stone under the tools while being dressed.

DRESSED WORK : That which is wrought on the face; also applied to stones having the joints wrought to a plane surface, but not "squared."

DRAFTED : Having a narrow chisel-draft cut around the face or margin.

DROVED, STROKED : Wrought with a broad chisel or hammer in parallel flutings across the stone from end to end.

HAMMER-DRESSED : Worked with the hammer.

HERRING-BONE : Dressed in angular flutings.

NIGGED or NIDGED : Picked with a pointed hammer or cavil to the desired form.

PATENT-HAMMERED : Dressed with a patent hammer.

PICKED : Reduced to an approximate plane with a pick.

PITCHED : Dressed to the neat lines or edges with a pitching-chisel.

PLAIN : Rubbed smooth to remove tool-marks.

POINTED : Dressed with a point or very narrow tool.

POLISHED : Rubbed down to a reflecting surface.

PRISON : Having surfaces wrought into holes.

RANDOM-TOOLED OR DROVED : Cut with a broad tool into irregular flutings.

ROCK-FACED, QUARRY-FACED, ROUGH : Left as it comes from the quarry. It may be drafted or pitched to reduce projecting points on the face to given limits.

RUBBED : See Plain.

RUSTIC, RUSTICATED : Having the faces of stones projecting beyond the arrises, which are bevelled or drafted. The face may be dressed in any desired manner.

SCABBLE : To dress off the angular projections of stones for rubble masonry with a stone-axe, or hammer.

SMOOTH : See Plain.

SQUARE-DROVED : Having the flutings perpendicular to the lower edge of the stone.

STRIPED : Wrought into parallel grooves with a point or punch.

STROKED : See Droved.

TOOLED : Wrought to a plane with an inch tool. See Droved.

TOOTHED : Dressed with a tooth-chisel.

VERMICULATED, WORM-WORK : Wrought into veins by cutting away portions of the face.

Inspection of Cut Stone.

The stone-cutter's shed should be frequently visited and the stones in hand examined (1) to discover any defects which have been overlooked in the examination of the rough stone; (2) for correctness of the dimensions; (3) character and quality of the workmanship. The dressing of the bed-joints should receive special attention. The surface of the bed should be true to the straight-edge placed in every direction across it. The practice of stone-cutters is to leave the beds a little "slack," i. e., concave. This should not be permitted without instructions from the chief. Stones with concave beds are liable to have their edges split off by the pressure, which, instead of being distributed over the whole area of the stone, is concentrated at the edges. The joints

formed by such stones are said to be *flushed.* They are difficult of detection after the masonry is built, and are often executed by design in order to give the face of the masonry a neat appearance, and therefore their occurrence must be guarded against by careful inspection of the progress of the stone-cutting.

If any part of the surface of the bed projects beyond the plane of the chisel-draft that projecting part will have to bear an undue share of the pressure which will be concentrated upon it, and the joint formed by such stones will gape at the edges forming what is called an *open joint.*

When the stone has been dressed so that all the small ridges on its surface are in one plane with the chisel-drafts the pressure is distributed with a near approach to uniformity for the mortar serves to transmit it to the furrows between the ridges.

Great smoothness is not desirable in the joints of masonry intended for strength and stability: a moderate degree of roughness adds to the resistance to sliding and to the adhesion of the mortar.

Moulded and rubbed work requires close watching, that the pieces may not be distorted or rubbed into hollow or concave patches.

PATCHED STONES.—Stones accidentally broken after being cut should not be allowed to be patched and used. The practice of patching is frequently followed in granite and other brittle stones The broken pieces are glued in with melted shellac. In dry weather and while still fresh from the tool such patches are hardly noticeable unless near the eye, therefore they should be closely looked for; but when the stone is wet by rain the patch becomes conspicuous, and as the shellac is slowly destroyed the piece may eventually drop out.

ASHLAR FACING.—The dressing of the face-stones which are to be backed with squared stones must be watched very closely, for the workmen seldom take the pains necessary to dress the beds and joints accurately; on the contrary, to obtain what are termed "close joints" they dress the joints with accuracy a few inches only from the outward surface, and then chip away the stone towards the back, so that when the block is set it will be in contact with the adjacent stones only throughout this very small extent of bearing surface. This practice is objectionable from every point of view: for, in the first place, it gives an inadequate extent of bearing surface, which, being generally insufficient to resist the pressure thrown on it, causes the block to splinter off

and, in the second place, to give the block its proper set it has to be propped up by small bits of stone, an operation called "spalling up," "pinning up," or underpinning, and these props, causing the pressure on the block to be thrown on a few points of the lower surface instead of being equally diffused over it, expose the stone to crack.

Mortar.

Mortar is made by mixing lime or cements with clean sand and adding just sufficient water to make a plastic mass The proportion of sand depends upon the character of the lime or cement.

CEMENT MORTAR —In mixing cement mortar the cement and sand are first thoroughly mixed dry, the water then added, and the whole worked to a uniformly plastic condition

The quality of the mortar depends largely upon the thoroughness of the mixing, the great object of which is to so thoroughly incorporate the ingredients that no two grains of sand shall lie together without an intervening layer or film of cement. To accomplish this the cement must be uniformly distributed through the sand during the dry mixing.

The mixers usually fail to thoroughly intermix the dry cement and sand, and to lighten the labor of the wet mixing they will give an overdose of water

In hand mixing there is great liability of errors in measuring out correct and uniform proportions of the prescribed materials

Mortar-men make mistakes which generally happen to be against the proper quantity of cement.

Packed cement when measured loose increases in volume to such an extent that a nominal 1 to 3 mortar is easily changed to an actual 1 to 4. When the specifications prescribe measure by volume the inspector should obtain definite directions from the engineer as to the manner in which the materials are to be measured, i. e., packed or loose.

The quantity of sand will also vary according to whether it is measured in a wet or dry condition, packed or loose.

On work of sufficient importance to justify some sacrifice of convenience the sand and cement should be proportioned by weight instead of by volume.

In mixing by hand a platform or box should be used; the sand and cement should be spread in layers with a layer of sand at the

bottom, then turned and mixed with shovels until a thorough incorporation is effected. The dry mixture should then be spread out, a bowl-like depression formed in the centre. and all the water required poured into it. The dry material from the outside of the basin should be thrown in until the water is taken up and then worked into a plastic condition, or the dry mixture may be shovelled to one end of the box and the water poured into the other end. The mixture of sand and cement is then drawn down with a hoe, small quantities at a time and mixed with the water until enough has been added to make a good stiff mortar

In order to secure proper manipulation of the materials on the part of the workmen it is usual to require that the whole mass shall be turned over a certain number of times with the shovels both dry and wet.

The mixing wet with the shovels must be performed quickly and energetically. The paste thus made should be vigorously worked with a hoe for several minutes to insure an even mixture. The mortar should then leave the hoe clean when drawn out of it, and very little should stick to the steel.

A large quantity of cement and sand should not be mixed dry and left to stand a considerable time before using, as the moisture in the sand will to some extent act upon the cement, causing a partial setting.

Upon large works mechanical mixers are frequently employed with the advantage of at once lessening the labor of manipulating the material and insuring good work.

The proportion of sand to cement depends upon the nature of the work and the necessity for the development of strength or imperviousness in the mortar. The relative quantities of sand and cement should also depend upon the nature of the sand; fine sand requires more cement than coarse This element is, however. not usually given the consideration it demands. (See Table 58)

The proportions required by the New York Building Laws of 1896 are as follows :

"Cement mortars shall be made of sand and cement in the proportion of not more than three parts of sand to one part of cement.

"Lime mortar shall be made of not more than four parts of sand to one part of lime, and shall not be used before being thoroughly slaked.

"Cement and lime mortar shall be made of one part of lime, one part of cement, and three parts of sand to each."

TABLE 58.

AMOUNT OF CEMENT AND SAND REQUIRED FOR ONE CUBIC YARD OF MORTAR.

Composition of Mortar by Volumes.		Cement.* Number of Barrels.		Sand. Cubic Yards.
Cement.	Sand.	Portland or Ulster County Rosendale	Western Rosendale.	
1	0	7.14	6.43	0.00
1	1	4 16	3.74	0 58
1	2	2.85	2.57	0.80
1	3	2.00	1.80	0.90
1	4	1 70	1 53	0.95
1	5	1.25	1.13	0.97
1	6	1.18	1.06	0.98
		Cement. Number of Pounds.†		
1	0	2675	2140	0 00
1	1	1440	1150	0.67
1	2	900	720	0.84
1	3	675	540	0.94
1	4	525	420	0 98
1	5	425	340	0.99
1	6	355	285	1.00

* Packed cement and loose sand.
† Loose cement and loose sand.

SAND FOR MORTAR.—The sand used *must be clean*, that is, free from clay. loam, mud. or organic matter; *sharp*, that is, the grains must be angular and not rounded as those from the beds of rivers and the seashore; *coarse*, that is, it must be large-grained, but not too uniform in size

The best sand is that in which the grains are of different sizes; the more uneven the sizes the smaller will be the amount of voids and hence the less cement required

WATER FOR MORTAR.—QUALITY.—The water employed for mortar should be fresh and clean, free from mud and vegetable matter.

Salt water may be used, but with some natural cements it may retard the setting, the chloride and sulphate of magnesia being the principal retarding elements. Less sea-water than fresh will be required to produce a given consistency.

QUANTITY.—The quantity of water to be used in mixing mortar can be determined only by experiment in each case. It depends upon the nature of the cement, upon that of the sand and of the water, and upon the proportions of sand to cement, and upon the purpose for which the mortar is to be used.

Fine sand requires more water than coarse to give the same consistency. Dry sand will take more water than that which is moist, and sand composed of porous material more than that which is hard. As the proportion of sand to cement is increased the proportion of water to cement should also increase, but in a much less ratio.

The amount of water to be used is such that the mortar when thoroughly mixed shall have a plastic consistency suitable for the purpose for which it is to be used.

The consistency of mortar for masonry is such that it will stand in a pile and not be fluid enough to flow. For concrete the consistency required is such that if a ball of mortar be formed in the hand and allowed to fall through a height of about 20 inches it will neither lose its form nor crack; the ball should not be wet enough to stick to the hand.

In all cases the proper quantity of water should first be determined by experiment upon small quantities of the materials, and afterwards, in preparing the mortar for use, the required quantity should each time be added by measurement.

The addition of water, little by little, or from a hose, should not be allowed.

Workmen, as a rule, add an excess of water for the purpose of reducing the labor of mixing.

From numerous experiments it has been found that, as a general rule, a proportion of 1 part of water to 3 parts of cement by measure, or 1 to 3½ by weight, is the best, both as regards convenience of mixing and results.

Effect of Retempering Mortar.

Masons very frequently mix mortar in considerable quantities, and if the mass becomes stiffened before being used, by the setting of the cement, add water and work it again to a soft or plastic condition. After this second tempering the cement is much less active than at first, and will remain for a longer time in a workable condition.

This practice is condemned by engineers, and is not usually allowed in good engineering construction. *Only sufficient quantity of mortar should be mixed at once as may be used before the cement takes the initial set. Reject all mortar that has set before being placed in the work.*

The mortar is placed on the work with the intention of its being used before it has taken its initial set. But masons like it extremely plastic, and before their mortar-boards are emptied they will make frequent calls to "temper up"; more water is added with remixing, and if oversight is relaxed the prescribed time of using it will have elapsed, and a diluted, weakened, and second-set material will have been used. Masons are so imbued with the belief that the "second set" is desirable and harmless that they will use every endeavor to obtain it. They will claim that it was permitted on some other notable work, and that it is unreasonable to prevent it, that they can do more work and with more ease, etc., etc. It is true that brick can be laid with more ease and rapidity with such mortar than when it is in proper condition; but it has been found that mortar that has taken its initial set and is remixed, with the addition of more water, loses about one half the tensile strength due to it if used in proper condition.

Freezing of Mortar.*—"It does not appear that common *lime mortar* is seriously injured by freezing, provided it remains frozen until it has fully set. The freezing retards, but does not entirely suspend, the setting. Alternate freezing and thawing materially damages the strength and adhesion of lime mortar.

"Although the strength of the mortar is not decreased by freezing, it is not always permissible to lay masonry during freezing weather; for example, if, in a thin wall, the mortar freeze before setting and afterwards thaw on one side only, the wall may settle injuriously.

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* Baker's "Masonry Construction."

"Mortar composed of one part *Portland cement* and three parts sand is entirely uninjured by freezing and thawing.

"Mortar made of *cements* of the *Rosendale type*, in any proportion, is entirely ruined by freezing and thawing."*

Mortar made of overclayed cement (which condition is indicated by its quicker setting), of either the Portland or Rosendale type, will not withstand the action of frost as well as one containing less clay; for since the clay absorbs an excess of water, it gives an increased effect to the action of frost.

In making cement mortar during freezing weather it is customary to add salt or brine to the water with which it is mixed. The ordinary rule is: Dissolve 1 pound of salt in 18 gallons of water when the temperature is at 32° F., and add 1 ounce of salt for each degree of lower temperature.

The use of salt, and more especially of sea-water, in mortar is objectionable, since the accompanying salts usually produce efflorescence.

The practice of adding hot water to lime mortar during freezing weather is undesirable. When the very best results are sought the brick or stone should be warmed—enough to thaw off any ice upon the surface is sufficient—before being laid. They may be warmed either by laying them on a furnace, or by suspending them over a slow fire, or by wetting with hot water.

Ashlar Masonry.

Ashlar masonry consists of blocks of stone cut to regular figures, generally rectangular, and built in courses of uniform height or rise, which is seldom less than a foot.

Size of the Stones.—In order that the stones may not be liable to be broken across no stone of a soft material, such as the weaker kinds of sandstone and granular limestone, should have a length greater than 3 times its depth or rise; in harder materials the length may be 4 or 5 times the depth. The breadth in soft materials may range from 1½ to double the depth; in hard materials it may be 3 times the depth.

Laying the Stone.—The bed on which the stone is to be laid should be thoroughly cleansed from dust and well moistened with water. A thin bed of mortar should then be spread evenly over it, and the stone, the lower bed of which has been cleaned and

* Trans. Am. Soc. of C. E., Vol. XVI. pp. 79-84.

moistened, raised into position, and lowered first upon one or two strips of wood laid upon the mortar-bed; then, by the aid of the pinch-bar, moved exactly into its place, truly plumbed, the strips of wood removed, and the stone settled in its place and levelled by striking it with wooden mallets. In using bars and rollers in handling cut stone the mason must be careful to protect the stone from injury by a piece of old bagging, carpet, etc.

In laying "rock-faced" work the line should be carried above it, and care must be taken that the work is kept plumb with the cut margins of the corners and angles.

THE THICKNESS OF MORTAR in the joints of well-executed ashlar masonry should be about $\frac{1}{8}$ of an inch, but it is usually about $\frac{3}{8}$.

AMOUNT OF MORTAR.—The amount of mortar required for ashlar masonry varies with the size of the blocks, and also with the closeness of the dressing. With $\frac{3}{8}$- to $\frac{1}{2}$-inch joints and 12- to 20-inch courses there will be about 2 cubic feet of mortar per cubic yard; with larger blocks and closer joints there will be about 1 cubic foot of mortar per yard of masonry. Laid in 1 to 2 mortar, ordinary ashlar will require $\frac{1}{4}$ to $\frac{1}{8}$ of a barrel of cement per cubic yard of masonry.

BOND OF ASHLAR MASONRY.—No side-joint in any course should be directly above a side-joint in the course below; but the stones should overlap or *break joint* to an extent of from once to once and a half the depth or rise of the course. This is called the *bond* of the masonry; its effect is to cause each stone to be supported by at least two stones of the course below, and assist in supporting at least two stones of the course above; and its objects are twofold: first, to distribute the pressure, so that inequalities of load on the upper part of the structure, or of resistance at the foundation, may be transmitted to and spread over an increasing area of bed in proceeding downwards or upwards, as the case may be; and secondly, to tie the structure together, or give it a sort of tenacity, both lengthwise and from face to back, by means of the friction of the stones where they overlap. The strongest bond in ashlar masonry is that in which each course at the face of the wall contains a header and a stretcher alternately, the outer end of each header resting on the middle of a stretcher of the course below, so that rather more than *one third* of the area of the face consists of ends of headers This proportion may be deviated from when circumstances require it; but in every case it is advisable that the ends of headers

should not form less than *one fourth* of the whole area of the face of the wall.

Squared-stone Masonry.

The distinction between squared-stone masonry and ashlar lies in the character of the dressing and the closeness of the joints. In this class of masonry the stones are roughly squared and roughly dressed on beds and joints, so that the width of the joints are half an inch or more. The same rules apply to breaking joint, and to the proportions which the lengths and breadths of the stones should bear to their depths, as in ashlar; and as in ashlar, also, *at least one fourth* of the face should consist of headers, whose length should be from three to five times the depth of the course.

AMOUNT OF MORTAR.—The amount of mortar required for squared-stone masonry varies with the size of the stones and with the quality of the masonry; as a rough average one sixth to one quarter of the mass is mortar. When laid in 1 to 2 mortar from $\frac{1}{2}$ to $\frac{3}{4}$ of a barrel of cement will be required per cubic yard of masonry.

Broken Ashlar.

Broken ashlar consists of cut stones of unequal depths laid in the wall without any attempt at maintaining courses of equal rise or the stones in the same course of equal depth. The character of the dressing and the closeness of the joints may be the same as in ashlar or squared-stone masonry, depending upon the quality desired. The same rules apply to breaking joint, and to the proportions which the lengths and breadths of the stones should bear to their depths, as in ashlar; and as in ashlar, also, *at least one fourth* of the face of the wall should consist of headers.

AMOUNT OF MORTAR.—The amount of mortar required when laid in 1 to 2 mortar will be from $\frac{3}{4}$ to 1 barrel per cubic yard of masonry, depending upon the closeness of the joints.

Rubble Masonry.

Masonry composed of unsquared stones is called *rubble*. This class of masonry covers a wide range of construction, from the commonest kind of dry-stone work to a class of work composed of large stones laid in mortar. It comprises two classes: (1) *uncoursed rubble*, in which irregular-shaped stones are laid without any attempt at regular courses, and (2) *coursed rubble*, in which the blocks of unsquared stones are levelled off at specified heights to an approximately horizontal surface. Coursed rubble is often built in *random courses;* that is to say, each course rests on a plane bed, but is not necessarily of the same depth or at the same level throughout, so that the beds occasionally rise or fall by steps. Sometimes it is required that the stone shall be roughly shaped with the hammer.

In building rubble masonry of any of the classes above mentioned the stone should be prepared by knocking off all the weak angles of the block. It should be cleansed from dust, etc., and moistened before being placed on its bed. Each stone should be firmly imbedded in the mortar. Care should be taken not only that each stone shall rest on its natural bed, but that the sides parallel to that natural bed shall be the largest, so that the stone may lie flat, and not be set on edge or on end. However small and irregular the stones, care should be taken to break joints. Side-joints should not form an angle with the bed-joint sharper than 60°. The hollows or interstices between the larger stones must be filled with smaller stones and carefully bedded in mortar.

One fourth part at least of the face of the wall should consist of *bond*-stones extending into the wall a length of at least 3 to 5 times their depth, as in ashlar.

AMOUNT OF MORTAR REQUIRED.—If rubble masonry is composed of small and irregular stones about $\frac{1}{3}$ of the mass will consist of mortar; if the stones are larger and more regular $\frac{1}{5}$ to $\frac{1}{4}$ will be mortar. Laid in 1 to 2 mortar, ordinary rubble requires from $\frac{1}{3}$ to 1 barrel of cement per cubic yard of masonry.

Inspection of Rubble Masonry.

The construction of rubble masonry requires constant watchfulness on the part of the inspector to see that the preceding rules are observed, and especially that the interior of the wall contains neither empty hollows nor spaces filled wholly with mortar or with rubbish where pieces of stone ought to be inserted, and that each stone is laid flat on its natural bed. Masons are very apt to set thin broad stones on their narrow edges so as to show a good face. The practice is injurious to the wall, for it exposes the bed of the stone to the destroying action of the atmosphere, and decreases the strength of the wall through lack of bonding.

See that the headers or bond-stones are really what they profess to be, and not thin stones set on edge at the face of the wall.

In bonding it is much better that many stones should reach two thirds across the wall alternately from the opposite faces than that there should be a few through stones extending the whole thickness of the wall. The bond-stones should not be directly over one another, but should be staggered.

Very long stones should not be used in the face; it is better to break them into two or more shorter ones.

The excessive use of spalls under large stones should not be allowed; the irregularities should be knocked off and the stones roughly bedded.

A fault to be carefully guarded against is that of making the wall consist of two thin faces or sides with through bond-stones laid across to bind them together, the core being filled in with mortar and small stones.

The placing of *nigger-heads* (field-stones or boulders from which the natural rounded surface has not been taken off) must not be permitted.

A small steel rod is a very useful implement for detecting the defects in rubble masonry by probing the vertical joints.

Ashlar backed with Rubble.

In this class of masonry the stones of the ashlar face should have their beds and joints accurately squared and dressed with the hammer or the points, according to the quality desired, for a breadth of from once to twice (or on an average once and a half) the depth or rise of the course, inwards from the face; but the backs of these stones may be rough. The proportion and length of the headers should be the same as in ashlar, and the "tails" of these headers, or parts which extend into the rubble backing, may be left rough at the back and sides; but their upper and lower beds should be hammer-dressed to the general plane of the beds of the course. These tails may taper slightly in breadth, but should not taper in depth.

The rubble backing built in the manner described under Rubble Masonry should be carried up at the same time with the face-work, and in courses of the same rise, the bed of each course being carefully formed to the same plane with that of the facing.

General Rules to be observed in Laying All Classes of Stone Masonry.

I. Build the masonry, as far as possible, in a series of courses, perpendicular, or as nearly so as possible, to the direction of the pressure which they have to bear, and by breaking joints avoid all long continuous joints parallel to that pressure.

II. Use the largest stones for the foundation-course.

III. Lay all stones which consist of layers in such a manner that the principal pressure which they have to bear shall act in a direction perpendicular, or as nearly so as possible, to the direction of the layers. This is called *laying the stone on its natural bed*, and is of primary importance for strength and durability.

IV. Moisten the surface of dry and porous stones before bedding them, in order that the mortar may not be dried too fast and reduced to powder by the stone absorbing its moisture.

V. Fill every part of every joint and all spaces between the stones with mortar, taking care at the same time that such spaces shall be as small as possible.

VI. The rougher the stones the better the mortar should be. The principal object of the mortar is to equalize the pressure; and the more nearly the stones are dressed to closely fitting sur-

faces the less important is the mortar. Not infrequently this rule is exactly reversed ; i. e., the finer the dressing the better the quality of the mortar used.

All projecting courses, such as sills, lintels, etc., should be covered with boards, bagging, etc., as the work progresses to protect them from injury and mortar-stains.

When setting cut stone a pailful of clean water should be kept at hand, and when any fresh mortar comes in contact with the face of the work it should be immediately washed off.

Brick Masonry.

GENERAL RULES TO BE OBSERVED IN BUILDING WITH BRICKS. —1. To reject all misshapen and unsound bricks.

2. To cleanse the surface of each brick, and to wet it thoroughly before laying it, in order that it may not absorb the moisture of the mortar too quickly.

3. To place the beds of the courses perpendicular, or as nearly perpendicular as possible, to the direction of the pressure which they have to bear ; and to make the bricks in each course break joint with those of the courses above and below by overlapping to the extent of from one quarter to one half of the length of a brick. (For the style of bond used in brick masonry see under Bond in list of definitions)

4. To fill every joint thoroughly with mortar.

Brick should not be merely *laid*, but every one should be rubbed and pressed down in such a manner as to force the mortar into the pores of the bricks and produce the maximum adhesion ; with quick-setting cement this is still more important than with lime mortar. For the best work it is specified that the brick shall be laid with a "shove-joint," that is, that the brick shall first be laid so as to project over the one below, and be pressed into the mortar, and then be shoved into its final position.

Bricks should be laid in full beds of mortar, filling end- and side-joints in one operation. This operation is simple and easy with skilful masons—if they will do it—but it requires persistence to get it accomplished. Masons have a habit of laying brick in a bed of mortar leaving the vertical joints to take care of themselves, throwing a little mortar over the top beds and giving a sweep with the trowel which more or less disguises the open joint below. They also have a way after mortar has been sufficiently applied to the top bed of brick to draw the point of their

trowel through it, making an open channel with only a sharp ridge of mortar on each side (and generally throwing some of it overboard), so that if the succeeding brick is taken up it will show a clear hollow, free from mortar through the bed. This enables them to bed the next brick with more facility and avoid pressure upon it to obtain the requisite thickness of joint.

With ordinary interior work a common practice is to lay brick with ½- and ¾-inch mortar-joints: an inspector whose duty it is to keep joints down to ¼ or ⅜ inch will not have an enviable task.

Neglect in wetting the brick before use is the cause of most of the failures of brickwork. Bricks have a great avidity for water, and if the mortar is stiff and the bricks dry they will absorb the water so rapidly that the mortar will not set properly, and will crumble in the fingers when dry. Mortar is sometimes made so thin that the brick will not absorb all the water. This practice is objectionable; it interferes with the setting of the mortar, and particularly with the adhesion of the mortar to the brick. Watery mortar also contracts excessively in drying (if it ever does dry), which causes undue settlement and, possibly, cracks or distortion.

The bricks should not be wetted to the point of saturation, or they will be incapable of absorbing any of the moisture from the mortar, and the adhesion between the brick and mortar will be weak.

The common method of wetting brick by throwing water from buckets or spraying with a hose over a large pile is deceptive. the water reaches a few brick on one or more sides and escapes many. Immersion of the brick for from 3 to 8 minutes, depending upon its quality, is the only sure method to avert the evil consequences of using dry or partially wetted brick.

Strict attention must be paid to have the starting course level, for the bricks being of equal thickness throughout, the slightest irregularity or incorrectness in it will be carried into the superimposed courses, and can only be rectified by using a greater or less quantity of mortar in one part or another, a course which is injurious to the work.

A common but improper method of building thick brick walls is to lay up the outer stretcher-courses between the header-courses, and then to throw mortar into the trough thus formed, making it semi-fluid by the addition of a large dose of water, then throwing in the brick (bats, sand, and rubbish are often substituted for bricks), allowing them to find their own bearing; when the

trough is filled it is plastered over with stiff mortar and the header-course laid and the operation repeated. This practice may have some advantage in celerity in executing work, but none in strength or security.

AMOUNT OF MORTAR REQUIRED.—The thickness of the mortar-joints should be about $\frac{1}{4}$ to $\frac{3}{8}$ of an inch. Thicker joints are very common, but should be avoided. If the bricks are even fairly good the mortar is the weaker part of the wall; hence the less mortar the better. Besides, a thin layer of mortar is stronger under compression than a thick one. The joints should be as thin as is consistent with their insuring a uniform bearing and allowing rapid work in spreading the mortar. The joints of outside walls should be thin in order to decrease the disintegration by weathering. The joints of inside walls are usually made from $\frac{3}{8}$ to $\frac{1}{2}$ inch thick.

The proportion of mortar to brick will vary with the size of the brick and with the thickness of the joint. With the standard brick ($8\frac{1}{4} \times 4 \times 2\frac{1}{4}$ inches) the amount of mortar required will be as follows:

Thickness of Joints.	Mortar required. Per Cubic Yard. Cubic Yards.	Per 1000 Brick. Cubic Yards.
$\frac{1}{2}$ to $\frac{5}{8}$ inch	0.30 to 0.40	0.80 to 0.90
$\frac{1}{4}$ " $\frac{3}{8}$ "	0.20 " 0.30	0.40 " 0.60
$\frac{1}{8}$ "	0.10 " 0.15	0.15 " 0.20

FACE- OR PRESSED-BRICK WORK.—This term is applied to the facing of walls with better bricks and thinner joints than the backing.

The bricks are pressed, of various colors, and are laid in colored mortar. The bricks are laid in close joint, usually $\frac{1}{8}$ inch thick, and set with an imperceptible batter in themselves, which may not be seen when looking at the work direct, but makes the joint a prominent feature and gives the work a good appearance. The brick of each course must be gauged with care and exactness, so that the joints may appear all alike. The bond used for the face of the wall is called the "running bond," the bricks are clipped on the back, and a binder placed transversely therein to bond the facing to the backing. The joints in the backing being thicker than those of the face-work, it is only in every six or seven courses that they come to the same level, so as to permit headers being put in. This class of work requires careful watch-

ing to see that the binders or headers are put in; it frequently happens that the face-work is laid up without having any bond with the backing.

In white-joint work the mortar is composed of white sand and fine lime putty. The mason when using this mortar spreads it carefully on the bed of the brick which is to be laid in such a way that when the brick is set the mortar will protrude about half an inch from the face of the wall. When there are a number laid, and before the mortar becomes too hard, the mortar that protrudes is cut off flush with the wall, the joint struck downwards, and the upper and lower edges cut with a knife guided by a small straight-edge. When the front is built the whole is cleaned down with a solution of muriatic acid and water, not too strong, and sometimes oiled with linseed-oil cut with turpentine and applied with a flat brush. After the front is thoroughly cleaned with the muriatic acid solution it should be washed with clean water to remove all remains of the acid.

When colored mortars are required the lime and sand should be mixed at least 10 days before the colored pigments are added to it, and they should be well soaked in water before being added to the mortar.

Brick Masonry Impervious to Water.

It sometimes becomes necessary to prevent the percolation of water through brick walls. A cheap and effective process has not yet been discovered and many expensive trials have proved failures. Laying the bricks in asphaltic mortar and coating the walls with asphalt or coal-tar are successful. "Sylvester's Process for Repelling Moisture from External Walls" has proved entirely successful. The process consists in using two washes for covering the surface of the walls, one composed of Castile soap and water, and one of alum and water. These solutions are applied alternately until the walls are made impervious to water.

Efflorescence.

Masonry, particularly in moist climates or damp places, is frequently disfigured by the formation of a white efflorescence on the surface. This deposit generally originates with the mortar. The water which is absorbed by the mortar dissolves the salts of soda, potash, magnesia, etc., contained in the lime or cement, and on evaporating deposits these salts as a white efflorescence on the surface. With lime mortar the deposit is frequently very heavy, and, usually, it is heavier with Rosendale than with Portland cement. The efflorescence sometimes originates in the brick, particularly if the brick was burned with sulphurous coal or was made from clay containing iron pyrites; and when the brick gets wet the water dissolves the sulphates of lime and magnesia, and on evaporating leaves the crystals of these salts on the surface. The crystallization of these salts within the pores of the mortar and of the brick or stone causes disintegration, and acts in many respects like frost.

The efflorescence may be entirely prevented by applying "Sylvester's" washes, composed of the same ingredients and applied in the same manner as for rendering masonry impervious to moisture. It can be much diminished by using impervious mortar for the face of the joints.

Repair of Masonry.

In effecting repairs in masonry, when new work is to be connected with old, the mortar of the old must be thoroughly cleaned off along the surface where the junction is to be made and the surface thoroughly wet. The bond and other arrangements will depend upon the circumstances of the case. The surfaces connected should be fitted as accurately as practicable, so that by using but little mortar no disunion may take place from settling.

As a rule, it is better that new work should butt against the old, either with a straight joint visible on the face, or let into a chase, sometimes called a "slip-joint," so that the straight joint may not show; but if it is necessary to bond them together the new work should be built in a quick-setting cement mortar and each part of it allowed to set before being loaded.

In pointing old masonry all the decayed mortar must be completely raked out with a hooked iron point and the surfaces well wetted before the fresh mortar is applied.

Definitions of the Terms used in Masonry.

ABUTMENT: 1. That portion of the masonry of a bridge or dam upon which the ends rest, and which connects the superstructure with the adjacent banks. 2. A structure that receives the lateral thrust of an arch.

ARRIS: The external angle or edge formed by the meeting of two plane or curved surfaces, whether walls or the sides of a stick or stone.

BACKED: Built on the rear face.

BACKING: The rough masonry of a wall faced with cut stone.

BATTER: The slope or inclination given to the face of a wall. It is expressed by dividing the height by the horizontal distance. It is described by stating the extent of the deviation from the vertical, as one in twelve, or one inch to the foot.

BATS: Broken bricks.

BEARING-BLOCKS OR TEMPLETS: Small blocks of stone built in the wall to support the ends of particular beams.

BELT-STONES OR -COURSES: Horizontal bands or zones of stone encircling a building or extending through a wall.

BLOCKING-COURSE: A course of stones placed on the top of a cornice, crowning the walls.

BOND.—The disposing of the blocks of stone or bricks in the wall so as to form the whole into a firm structure by a judicious overlapping of each other so as to break joint.

A stone or brick which is laid with its length across the wall, or extends through the facing-course into that behind, so as to bind the facing to the backing, is called a "header" or "bond."

Bonds are described by various names, as:

Binders, when they extend only a part of the distance across the wall.

Through-bonds, when they extend clear across from face to back.

Heart-bond, when two headers meet in the middle of the wall and the joint between them is covered by another header.

Perpend-bond signifies that a header extends through the whole thickness of the wall.

Chain-bond is the building into the masonry of an iron bar, chain, or heavy timber.

Cross-bond: A bond in which the joints of the second stretcher-course come in the middle of the first; a course composed of headers and stretchers intervening.

Block- and cross-bond: The face of the wall is put up in cross-bond and the backing in block-bond.

English bond (brick masonry) consists of alternate courses of headers and stretchers.

Flemish-bond (brick masonry) consists of alternate headers and stretchers in the same course.

Blind bond is used to tie the front course to the wall in pressed-brick work where it is not desirable that any headers should be seen in the face-work.

To form this bond the face-brick is trimmed or clipped off at both ends, so that it will admit a binder to set in transversely from the face of the wall, and every layer of these binders should be tied with a header-course the whole length of the wall. The binders should be put in every fifth course, and the backing should be done in a most substantial manner, with hard brick laid in close joint, for the reason that the face-work is laid in a fine putty mortar, and the joints consequently close and tight; and if the backing is not the same the pressure upon the wall will make it settle and draw the wall inward.

The common form of bond in brickwork is to lay three or five courses as stretchers; then a header-course.

BOND-STONES IN PIERS.—"Every pier built of brick, containing less than nine superficial feet at the base, supporting any beam, girder, arch, or column on which a wall rests, or lintel spanning an opening over ten feet and supporting a wall, shall at intervals of not over thirty inches apart in height have built into it a bond-stone not less than four inches thick, or a cast-iron plate of sufficient strength, and the full size of the piers." (N. Y. Building Laws, 1896.)

BREAST-WALL: One built to prevent the falling of a vertical face cut into the *natural* soil; in distinction to a retaining wall, etc.

BRICK ASHLAR: Walls with ashlar facing backed with bricks.

BUILD OR RISE: That dimension of the stone which is perpendicular to the quarry-bed.

BUTTRESS: A vertical projecting piece of stone or brick masonry built in front of a wall to strengthen it.

CLOSERS are pieces of brick or stone inserted in alternate courses of brick and broken ashlar masonry to obtain a bond.

CLEANING DOWN consists in washing and scrubbing the stone-work with muriatic acid and water. Wire brushes are generally used for marble and sometimes for sandstone. Stiff bristle

brushes are ordinarily used. The stones should be scrubbed until all mortar-stains and dirt are entirely removed.

For cleaning old stonework the sand-blast operated either by steam or compressed air is used. Brick masonry is cleaned in the same manner as stone masonry. During the process of cleaning all open joints under window-sills and elsewhere should be pointed.

COPING.—The coping of a wall consists of large and heavy stones, slightly projecting over it at both sides, accurately bedded on the wall, and jointed to each other with cement mortar. Its use is to shelter the mortar in the interior of the wall from the weather, and to protect by its weight the smaller stones below it from being knocked off or picked out. Coping-stones should be so shaped that water may rapidly run off from them.

For coping-stones the objections with regard to excess of length do not apply; this excess may, on the contrary, prove favorable, because, the number of top joints being thus diminished, the mass beneath the coping will be better protected.

Additional stability is given to a coping by so connecting the coping-stones together that it is impossible to lift one of them without at the same time lifting the ends of the two next it. This is done either by means of iron cramps inserted into holes in the stones and fixed there with lead, or, better still, by means of dowels of wrought iron, cast iron, copper, or hard stone. The metal dowels are inferior in durability to those of hard stone, though superior in strength. Copper is strong and durable, but expensive. The stone dowels are small prismatic or cylindrical blocks, each of which fits into a pair of opposite holes in the contiguous ends of a pair of coping-stones and fixed with cement mortar.

The under edge should be *throated* or dripped, that is, grooved, so that the drip will not run back on the wall, but drop from the edge.

Coping is divided into three kinds:

Parallel coping, level on top. *Feather-edged coping*, bedded level and sloping on top. *Saddle-back coping* has a curved or doubly inclined top.

CORBEL: A horizontal projecting piece or course of masonry which assists in supporting one resting upon it which projects still further.

CORNICE: The ornamental projection at the eaves of a building or at the top of a pier or any other structure.

COUNTERFORT: Vertical projections of stone or brick masonry built at intervals along the *back* of a wall to strengthen it, and generally of very little use.

COURSE.—The term course is applied to each horizontal row or layer of stones or bricks in a wall; some of the courses have particular names, as:

Plinth-course, a lower, projecting, square-faced course; also called the *water-table*.

Blocking course, laid on top of the cornice.

Bonding-course, one in which the stones or bricks lie with their length across the wall; also called *heading* course.

Stretching-course, consisting of stretchers.

Springing-course, the course from which an arch springs.

String-course, a projecting course.

Rowlock-course, bricks set on edge.

CRAMPS: Bars of iron having the ends turned at right angles to the body of the bar, and inserted in holes and trenches cut in the upper sides of adjacent stones to hold them together (see under Coping).

CUTWATER OR STARLING: The projecting ends of a bridge-pier, etc., usually so shaped as to allow water, ice, etc., to strike them with but little injury.

DOWELS.—Straight bars of iron, copper, or stone which are placed in holes cut in the upper bed of one stone and in the lower bed of the next stone above. They are also placed horizontally in the adjacent ends of coping-stones (see under Coping). Cramps and dowels are fastened in place by pouring melted lead, sulphur, or cement grout around them.

DRY STONE WALLS may be of any of the classes of masonry previously described, with the single exception that the mortar is omitted. They should be built according to the principles laid down for the class to which they belong.

FACE: The front surface of the wall.

FACING: The stone which forms the face or outside of the wall exposed to view.

FOOTING: The projecting courses at the base of a wall for the purpose of distributing the weight over an increased area, and thereby diminishing the liability to vertical settlement from compression of the ground.

Footings, to have any useful effect, must be securely bonded into the body of the work, and have sufficient strength to resist the cross-strains to which they are exposed.

The beds should be dressed true and parallel.

Too much care cannot be bestowed upon the footing-courses of any building, as upon them depends much of the stability of the work. If the bottom course be not solidly bedded, if any rents or vacuities are left in the beds of the masonry, or if the materials be unsound or badly put together, the effects of such carelessness will show themselves sooner or later, and always at a period when remedial efforts are useless.

FOOTING-COURSES.—(N. Y. Building Laws, 1896): "The footing- or base-course shall be of stone or concrete, or both, or of concrete and stepped-up brickwork, of sufficient thickness and area to safely bear the weight to be imposed thereon. If the footing- or base-course be of concrete, the concrete shall not be less than 12 inches thick; if of stones, the stones shall not be less than 2 by 3 feet, and at least 8 inches in thickness for walls, and at least 12 inches wider than the bottom width of said walls, and not less than 10 inches in thickness if under piers, columns, or posts. All base-stones shall be well bedded and laid crosswise, edge to edge."

If, in place of a continuous foundation-wall, isolated piers are to be built to support the superstructure, where the nature of the ground and the character of the building make it necessary, inverted arches shall be turned between the piers, at least 12 inches thick and of the full width of the piers, and resting upon a continuous bed of concrete of sufficient area, and at least 18 inches thick; or two footing-courses of large stone may be used, the bottom course to be laid crosswise, edge to edge, and the top course laid lengthwise, end to end; or one course of concrete and one course of stone. The stones shall not be less than 10 inches thick in each course, and the concrete shall not be less than 18 inches thick, and the area of the lower course shall be equal to the area of the base-course that would be required under a continuous wall, and the outside pier shall be secured to the second pier with suitable iron rods and plates.

"If stepped-up footings of brick are used in place of stone above the concrete the steps or offsets, if laid in single courses, shall each not exceed 1½ inches, or, if laid in double courses, then each shall not exceed three inches, starting with the brickwork covering the entire width of the concrete."

Chicago Building Ordinances, 1893: "The offsets of foundations of concrete alone shall not exceed one-half the height of the respective courses. If reinforced by rails or beams the offsets

must be so adjusted that the fibre-strain per square inch shall not exceed 12,000 pounds for iron or 16,000 pounds for steel.

"The offsets in layers of dimension stone must not be more than three quarters of the height of the individual stones.

"In brick piers there shall be at every offset a bond-stone at least 8 in. thick, and at the top of each pier a cap-stone at least 10 in. thick, or in all such cases a bond-plate of cast or rolled iron."

GAUGED-WORK: Bricks cut and rubbed to the exact shape required.

GROUT is a thin or fluid mortar made in the proportion of 1 of cement to 1 or 2 of sand.

It is used to fill up the voids in walls of rubble masonry and brick. Sometimes the interior of a wall is built up dry and grout poured in to fill the voids. Unless specifically instructed to permit its use, grout should not be used unless in the presence of the inspector. When used by masons without instructions it is usually for the purpose of concealing bad work.

Grout is used for solidifying quicksand. A series of pipes are sunk into the layer of quicksand, and through each alternate one cement grout is forced under pressure. This seeking an outlet by the line of least resistance, will make an exit by the adjoining pipe, which opens into the air above; but in so doing the pressure-valve at the bottom of the pipe is opened and results in a diffusing of the grout in the surrounding quicksand, which forms with it an artificial stone, and by gradually raising the pipes a wall of stone is formed in the layer of quicksand.

The term *grout* is also applied to the waste stone in quarries.

GROUTING is pouring fluid mortar over last course for the purpose of filling all vacuities.

HEADER.—Also called a bond. A stone or brick whose greatest dimension lies perpendicular to the face of the wall, and used for the purpose of tying the face to the backing (see Bond). A trick of masons is to use "blind headers," or short stones that look like headers on the face, but do not go deeper into the wall than the adjacent stretchers. When a course has been put on top of these they are completely covered up, and, if not suspected, the fraud will never be discovered unless the weakness of the wall reveals it.

In facing brick walls with pressed brick the bricklayer will frequently cut the headers for the purpose of economizing the more expensive material; thus great watchfulness is necessary to secure a good bond between the facing and common brick.

HEADERS.—N. Y. Building Laws, 1896: "All stone foundation-walls 24 inches or less in thickness shall have at least one header extending through the wall in every 3 feet in height from the bottom of the wall, and in every 4 feet in length, and if over 24 inches in thickness shall have one header for every 6 superficial feet on both sides of the wall, and running into the wall at least 2 feet. All headers shall be at least 18 inches in width and 8 inches in thickness, and consist of good, flat stone.

"In all brick walls every sixth course shall be a heading-course, except where walls are faced with brick in running bond, in which latter case every sixth course shall be bonded into the backing by cutting the course of the face-brick and putting in diagonal headers behind the same, or by splitting the face-brick in half and backing the same with a continuous row of headers."

JOINTS.—The mortar layers between the stones or bricks are called the joints. The horizontal joints are called "bed-joints"; the end-joints are called the vertical joints, or simply the "joints."

Excessively thick joints should be avoided. In good brick-work they should be about $\frac{1}{4}$ to $\frac{3}{8}$ inch thick; for ashlar masonry and pressed-brick work about $\frac{1}{8}$ to $\frac{1}{16}$ inch thick; for rubble masonry they vary according to the character of the work.

The joints of both stone and brick masonry are finished in different ways, with the object of presenting a neat appearance and of throwing the rain-water away from the joint.

Flush Joints.—In these the mortar is pressed flat with the trowel and the surface of the joint is flush with the face of the wall.

Struck-joints are formed by pressing or striking back with the trowel the upper portion of the joint while the mortar is moist, so as to form an outward sloping surface from the bottom of the upper course to the top of the lower course. This joint is also designated by the name "weather-joint." Masons generally form this joint so that it slopes inwards, thus leaving the upper arris of the lower course bare and exposed to the action of the weather. The reason for forming it in this improper manner is that it is easier to perform.

Keyed Joints are formed by drawing a curved iron key or jointer along the centre of the flushed joint, pressing it hard, so that the mortar is driven in beyond the face of the wall, a groove of curved section is thus formed, having its surface hardened by the pressure.

White-skate or Groove Joint is employed in front brick-work. It is about $\frac{3}{16}$ inch thick. It is formed with a jointer having the width of the intended joint. It is guided along the joint by a straight-edge and leaves its impress upon the material.

JOGGLE: A joint-piece or dowel-pin let into adjacent faces of two stones to hold them in position. It may vary in form, and approach in its shape either the dowel or clamp.

JAMB: The sides of an opening left in a wall.

LINTEL: The stone, wood, or iron beam used to cover a narrow opening in a wall.

STONE LINTELS.

(N. Y. Building Laws, 1896.)

Width of Opening.	Dimensions of Lintel.		
	Height.	Thickness.	Bearing.
4 ft.	8 in.	4 in.	5 in.
6 "	12 "	4 "	......
6 to 8 ft.	12 "	......	......

"On the inside of all openings in which the stone lintel shall be less than the thickness of the wall to be supported there shall be a good timber lintel on the inside of the stone lintel, which shall rest at each end not more than 3 inches on any wall, and shall be chamfered at each end, and shall have a double row-lock or bonded arch turned over the timber lintel. Or the inside lintel may be of cast iron, and in such case stone blocks or cast-iron plates shall not be required at the ends where the lintels rest on the walls, provided the opening is not more than six feet in width."

ONE-MAN STONE: A stone of such size as to be readily lifted by one man.

PARAPET WALL is a low wall running along the edge of a terrace or roof to prevent people from falling over.

"All exterior and division or party walls over fifteen feet high, excepting where such walls are to be finished with cornices, gutters, or crown mouldings, shall have parapet walls carried two

feet above the roof, and shall be coped with stone, well-burnt terra-cotta, or cast iron." (N. Y. Building Laws, 1896.)

POINTING a piece of masonry consists in scraping out the mortar in which the stones were laid from the face of the joints for a depth of from ½ to 2 inches, and filling the groove so made with clear Portland-cement mortar or with mortar made of 1 part of cement and 1 part of sand.

The object of pointing is that the exposed edges of the joints are always deficient in density and hardness, and the mortar near the surface of the joint is specially subject to dislodgment, since the contraction and expansion of the masonry are liable either to separate the stone from the mortar or to crack the mortar in the joint, thus permitting the entrance of rain-water, which freezing forces the mortar from the joints.

The pointing-mortar, when ready for use, should be rather incoherent and quite deficient in plasticity.

Before applying the pointing the joint must be well cleansed by scraping and brushing out the loose matter, then thoroughly saturated with water, and maintained in such a condition of dampness that the stones will neither absorb water from the mortar nor impart any to it. Walls should not be allowed to dry too rapidly after pointing.

Pointing should not be prosecuted either during freezing or excessively hot weather.

The pointing-mortar is applied with a mason's trowel, and the joint well calked with a calking-iron and hammer. In the very best work the surface of the mortar is rubbed smooth with a steel polishing-tool. The form given to the finished joint is the same as described under Joints.

Pointing with colored mortar is frequently employed to improve the appearance of the work. Various colors are used, as white, black, red, brown, etc., different-colored pigments being added to the mortar to produce the required color

Tuck-pointing, used chiefly for brickwork, consists of a projecting ridge with the edges neatly pared to an uniform breadth of about ⅜ inch. White mortar is usually employed for this class of pointing.

Many authorities consider that pointing is not advisable for new work, as the joints so formed are not as enduring as those which are finished at the time the masonry is built. Pointing is, moreover, often resorted to when it is intended to give the work

a superior appearance, and also to conceal defects in inferior work.

PALLETS, PLUGS: Wooden bricks inserted in walls for fastening trim, etc.

PLINTH: A projecting base to a wall; also called "water-table."

QUARRY-FACED OR ROCK-FACED MASONRY: That in which the face of the stone is left untouched as it comes from the quarry.

PITCHED-FACE MASONRY: That in which the face of the stone is roughly dressed with the pitching-chisel so as to give edges that are approximately true.

QUOIN: A corner-stone. A quoin is a header for one face and a stretcher for the other.

RIP-RAP.—Rip-rap is composed of rough undressed stone as it comes from the quarry, laid dry about the base of piers, abutments, slopes of embankments, etc., to prevent scour and wash. When used for the protection of piers the stones are dumped in promiscuously, their size depending upon the material and the velocity of the current. Stones of 15 to 25 cubic feet are frequently employed. When used for the protection of banks the stones are laid by hand to a uniform thickness.

RISE: That dimension of a stone which is perpendicular to its quarry-bed (see Build).

RETAINING WALL OR REVETMENT: A wall built to retain earth *deposited* behind it (see Breast-wall).

REVEAL: The exposed portion of the sides of openings in walls in front of the recesses for doors, window-frames, etc.

SLOPE-WALL MASONRY: A slope-wall is a thin layer of masonry used to protect the slopes of embankments, excavations, canals, river-banks, etc., from rain, waves, weather, etc.

SLIPS: See Wood Bricks.

SPALL.—A piece of stone chipped off by the stroke of a hammer.

SILL.—The stone, iron, or wood on which the window or door of a building rests.

In setting stone sills the mason beds the ends only; the middle is pointed up after the building is enclosed. They should be set perfectly level lengthwise, and have an inclination crosswise, so the water may flow from the frame.

STONE PAVING consists of roughly squared or unsquared blocks of stone used for paving the waterway of culverts, etc., it is laid both dry and in mortar.

STARLING: See Cutwater.

STRETCHER: A stone or brick whose greatest dimension lies parallel to the face of the wall.

STRING-COURSE: A horizontal course of brick or stone masonry projecting a little beyond the face of the wall. Usually introduced for ornament.

TEMPLETS: Bearing-blocks; small blocks of stone inserted in the wall to support the ends of particular beams.

TWO-MEN STONE: Stone of such size as to be conveniently lifted by two men.

TOOTHING: Unfinished brickwork so arranged that every alternate brick projects half its length.

WATER-TABLE: See Plinth.

WOOD BRICKS, PALLETS, PLUGS, OR SLIPS are pieces of wood laid in a wall in order the better to secure any woodwork that it may be necessary to fasten to it. Great injury is often done to walls by driving wood plugs into the joints, as they are apt to shake the work. Hollow porous terra-cotta bricks are frequently used instead of wood, bricks, etc.

WALLS are constructions of stone, brick, or other materials, and serve to retain earth or water, or in buildings to support the roof and floors and to keep out the weather. The following points should be attended to in the construction of walls:

The whole of the walling of a building should be carried up simultaneously; no part should be allowed to rise more than about 3 feet above the rest; otherwise the portion first built will settle down to its bearings before the other is attached to it, and then the settlement which takes place in the newer portion will cause a rupture, and cracks will appear in the structure. If it should be necessary to carry up one part of a wall before the other, the end of that portion first built should be *racked back*, that is, left in steps, each course projecting farther than the one above it.

Work should not be hurried along unless done in cement mortar, but given time to settle to its bearings.

Anchoring Walls.—N. Y. Building Laws, 1896: "In no case shall any wall or walls of any buildings be carried up more than two stories in advance of any other wall. The front, rear, side, and party walls shall be properly bonded together, or anchored to each other every six feet in their height by wrought-iron anchors, not less than one and a half inches by three eighths of an inch in size. The side anchors shall be built into the side

or party walls not less than sixteen inches, and into the front and rear walls, so as to secure the front and rear walls to the side or party walls, when not built and bonded together."

Bracing Walls during Erection.—"The walls of every building, during the erection or alteration thereof, shall be strongly braced from the beams of each story, and when required shall also be braced from the outside, until the building is enclosed. The roof tier of wooden beams shall be safely anchored with plank or joist to the beams of the story below until the building is enclosed." (N. Y. Building Laws, 1896.)

Curtain walls of brick built in between iron or steel columns, and supported wholly or in part on iron or steel girders, shall not be less than twelve inches thick for fifty feet of the uppermost height thereof, and every lower section of fifty feet, or part thereof, shall have a thickness of four inches more than is required for the section next above it, down to the tier of beams nearest to the curb-level.

Projection of Brick in Furred Walls.—"In all furred walls the course of brick above the under side and below the top of each tier of floor-beams shall project the thickness of the furring, to more effectually prevent the spread of fire." (N. Y. Building Laws, 1896.)

Recesses in Walls. — "No recess for water or other pipes shall be made in any wall more than one third of its thickness, and the recesses around said pipe or pipes shall be filled up solid with masonry for the space of one foot at the top and bottom of each story." (N. Y. Building Laws, 1896.)

Thickness of Walls.

(N. Y. Building Laws, 1896.)

Dwelling-houses, Hotels, and Schools.

35 *feet high,* 20 *feet wide.*

Basement	12 inches
Exterior	8 "
Party	12 "

35 *to* 50 *feet high,* 26 *feet wide.*

Above foundation-wall	12 inches

50 *to* 60 *feet high.*

Above basement if a high-stoop house	12 inches
If not a high-stoop house, first story	16 "

60 *to* 75 *feet high.*

First 25 ft	16 inches
Thence to top	12 "

75 *to* 85 *feet high.*

First 20 ft	20 inches
20 ft. to 60 ft	16 "
Thence to top	12 "

85 *to* 100 *feet high.*

First 35 ft	24 inches
35 ft. to 75 ft	20 "
Thence to top	16 "

100 *to* 115 *feet high.*

First 25 ft	28 inches
25 ft. to 50 ft	24 "
50 ft. to 90 ft	20 "
Thence to top	16 "

Over 115 *feet high.*

Increase each additional 25 feet in height or part thereof next above the curb 4 inches, the upper 115 feet remaining the same as specified for wall of that height.

Partition-walls 8 inches thick shall not be built vertically more than 50 feet.

WAREHOUSES, STORES, FACTORIES, ETC.

40 feet high, 25 feet wide.

	12 inches

40 to 60 feet high.

First 40 ft.	16 inches
Thence to top	12 "

60 to 75 feet high.

First 25 ft.	20 inches
Thence to top	16 "

75 to 85 feet.

First 20 ft.	24 inches
20 ft. to 60 ft	20 "
Thence to top	16 "

85 to 100 feet.

First 25 ft.	28 inches
25 ft. to 50 ft.	24 "
50 ft. to 75 ft.	20 "
Thence to top	16 "

If over 100 ft. each additional 25 ft. or part thereof next above the curb shall be increased 4 inches in thickness, the upper 100 ft. remaining as specified for walls of that height.

Safe Working Loads for Masonry.

BRICK MASONRY IN WALLS OR PIERS.

	Tons per Sq. Ft.
Hard brick in lime mortar	5 to 7
" " " Rosendale cement 1 to 3	8 " 10
Pressed brick in lime mortar	6 " 8
" " " Rosendale cement	9 " 12
" " " Portland "	12 " 15

Piers exceeding in height six times their least dimension should be increased 4 inches in size for each additional 6 feet.

According to the New York Building Laws, brickwork in good lime mortar 8 tons per sq. ft., 11¼ tons when good lime and

cement mortar is used, and 15 tons when good cement mortar is used.

According to the Boston Building Laws:

	lbs. per Sq. Ft.
Best hard-burned brick (height less than six times least dimension) with	
Mortar, 1 cement, 2 sand	30,000
" 1 " 1 lime, 3 "	24,000
" lime	16,000
Best hard-burned brick (height six to twelve times least dimension) with	
Mortar, 1 cement, 2 sand	26,000
" 1 " 1 lime, 3 "	20,000
" lime	14,000

For light hard-burned brick use ⅔ the above amounts.

Stone Masonry.

	Tons per Sq. Ft.
Rubble walls, irregular stones	3
" " coursed, soft stone	2½
" " " hard stone	5 to 16
Dimension stone in cement:	
Sandstone and limestone	10 " 20
Granite	20 " 40
Dressed stone, with ⅜-inch dressed joints, in cement:	
Granite	60
Marble or limestone	40
Sandstone	30

Height of columns not to exceed eight times least diameter.

Mortars.

	Tons per Sq. Ft.
In ½ inch joints 3 months old:	
Portland cement 1 to 4	40
Rosendale " 1 " 3	18
Lime mortar	8 to 10
Portland 1 to 2 in ¼-inch joints for bedding iron plates	70

Concrete.

	Tons per Sq. Ft.
Portland cement 1 to 8	8 to 20
Rosendale " 1 " 6	5 " 10
Lime, best, 1 to 6	5

HOLLOW TILE.

	Pounds per Sq. Ft.
Hard fire-clay tiles....................................	80
" ordinary clay tiles..............................	60
Porous terra-cotta "	40
Terra-cotta blocks, unfilled,........................	10,000
" " filled solid with brick or cement..	20,000

Description of Arches.

BASKET-HANDLE ARCH: One in which the intrados resembles a semi-ellipse, but is composed of arcs of circles tangent to each other.

CATENARIAN ARCH: One whose intrados is a catenary.

CIRCULAR ARCH: One in which the intrados is a part of a circle.

DISCHARGING ARCH: An arch built above a lintel to take the superincumbent pressure therefrom.

ELLIPTICAL ARCH: One in which the intrados is a part of an ellipse.

GEOSTATIC ARCH: An arch in equilibrium under the vertical pressure of an earth embankment.

HYDROSTATIC ARCH: An arch in equilibrium under the vertical pressure of water.

INVERTED ARCHES are like ordinary arches, but are built with the crown downwards. They are generally semicircular or segmental in section, and are used chiefly in connection with foundations.

PLAIN OR ROUGH ARCHES are those in which none of the bricks cut to fit the splay. Hence the joints are quite close to each other at the soffit, are wider towards the outer curve of the arch; they are generally used as *relieving*, trimmer, *tunnel-lining*, and all arches where strength is essential and appearance no particular object. In constructing arches of this kind it is usual to form them of two or more four-inch concentric rings until the required thickness is obtained. Each of the successive rings is built independently, having no connection with the others beyond the adhesion of the mortar in the ring-joint. It is necessary that each ring should be finished before the next is commenced; also that each course be bounded throughout the length of the arch, and

that the ring-joint should be of a regular thickness. For if one ring is built with a thin joint and another with a thick one the one having the most mortar will shrink, causing a fracture and depriving the arch of much of its strength.

POINTED ARCH: One in which the intrados consists of two arcs of equal circles intersecting over the middle of the span.

RELIEVING ARCH: See Discharging Arch.

RIGHT ARCH: A cylindrical arch, either circular or elliptical, terminated by two planes, termed *heads* of the arch, at right angles to the axis of the arch.

SEGMENTAL ARCH: One whose intrados is less than a semicircle.

SEMICIRCULAR ARCH: One whose intrados is a semicircle, also called a *full-centred* arch.

SKEW ARCH: One whose heads are oblique to the axis. Skew arches are quite common in Europe, but are rarely employed in the United States; and in the latter when an oblique arch is employed it is usually made, not after the European method with spiral joints, but by building a number of short right arches or ribs in contact with each other, each successive rib being placed a little to one side of its neighbor.

Definitions of Parts of Arches.

ABUTMENT: The outer wall that supports the arch, and which connects it to the adjacent banks.

ARCH-SHEETING: The voussoirs which do not show at the end of the arch.

CAMBER is a slight rise of an arch, as $\frac{1}{8}$ to $\frac{1}{4}$ inch per foot of span.

CROWN: The highest point of the arch.

EXTRADOS: The upper and outer surface of the arch.

HAUNCHES: The sides of the arch, from the springing-line halfway up to the crown.

HEADING-JOINT: A joint in a plane at right angles to the axis of the arch. It is not continuous.

INTRADOS OR SOFFIT: The under or lower surface of the arch.

INVERT: An inverted arch, one with its intrados below the axis or springing-line; e. g., the lower half of a circular sewer.

KEYSTONE: The centre voussoir at the crown.

LENGTH : The distance between face-stones of the arch.

PIER : The intermediate support for two or more arches.

RING-COURSE : A course parallel to the face of the arch.

RING-STONES : The voussoirs or arch-stones which show at the ends of the arch.

RISE : The height from the springing-line to under side of the arch at the keystone.

SKEW-BACK : The upper surface of an abutment or pier from which an arch springs ; its face is on a line radiating from centre of arch.

SPAN : The horizontal distance from springing to springing of the arch.

SPANDREL : The space contained between a horizontal line drawn through the crown of the arch and a vertical line drawn through the upper end of the skew-back.

SPRINGING : The point from which the arch begins or springs.

SPRINGER : The lowest voussoir or arch-stone.

STRING-COURSE : A course of voussoirs extending from one end of the arch to the other.

VOUSSOIRS : The blocks forming the arch.

Construction of Arches.

In constructing ornamental arches of small span the bricks should be cut and rubbed with great care to the proper splay or wedge like form necessary, and according to the gauges or regularly measured dimensions.

This is not always done, the external course only being rubbed, so that the work may have a pleasing appearance to the eye, while the interior, which is hidden from view, is slurred over, and in order to save time many of the interior bricks are apt to be so cut away as to deprive the arch of its strength. This class of work produces cracks and causes the arch to bulge forward, and may cause one of the bricks of a straight arch to drop down lower than the soffit.

In setting arches the mason should be sure that the centres are set *level* and *plumb*, that the arch-brick or -stone may rest upon them *square*. When the brick or stone are properly cut beforehand the courses can be gauged upon the centre from the key downwards. The soffit of each course should fit the centre perfectly.

The mortar-joints should be as thin as possible and well flushed up.

In setting the face-stones it is necessary to have a radius-line, and draw it up and test the setting of each stone as it is laid.

The framing, setting up, and striking of the centres are very important parts of the construction of any arch, particularly one of long span. A change in the shape of the centre, due to insufficient strength or improper bracing, will be followed by a change in the curve of the intrados, and consequently of the line of resistance, which may endanger the safety of the arch itself.

Centring for Arches.

No arch becomes self-supporting until keyed up, that is, until the crown- or keystone-course is laid. Until that time the arch-ring, which should be built up simultaneously from both abutments, has to be supported by frames called centres. These consist of a series of ribs placed from 3 to 6 or more feet apart, supported from below. The upper surface of these ribs is cut to the form of the arch, and over these a series of planks called *laggings* are placed, upon which the arch-stones directly rest. The ribs may be of timber or iron. They should be strong and stiff. Any deformation that occurs in the rib will distort the arch, and may even result in its collapse.

STRIKING THE CENTRE.—The ends of the ribs or centre-frames usually rest upon a timber lying parallel to, and near, the springing-line of the arch. This timber is supported by wedges, preferably of hardwood, resting upon a second stick, which is in turn supported by wooden posts, usually one under each end of each rib. The wedges between the two timbers, as above, are used in removing the centre after the arch is completed, and are known as *striking-wedges*. They consist of a pair of folding wedges, 1 to 2 feet long, 6 inches wide, and having a slope of from 1 to 5 to 1 to 10, placed under each end of each rib. It is necessary to remove the centres slowly, particularly for large arches; and hence the striking-wedges should have a very slight taper, the larger the span the smaller the taper.

The centre is lowered by driving back the wedges. To lower the centre uniformly the wedges must be driven back uniformly. This is most easily accomplished by making a mark on the side of

each pair of wedges before commencing to drive, and then *moving* each the same amount.

The inclined surfaces of the wedges should be lubricated when the centre is set up, so as to facilitate the striking.

Screws may be used instead of wedges for lowering centres.

Sand is also employed for the same purpose. The method followed is to support the centre-frames by wooden pistons or plungers resting on sand confined in plate-iron cylinders. Near the bottom of each cylinder there is a plug which can be withdrawn and replaced at pleasure, thus regulating the outflow of the sand and the descent of the centre.

There is great difference of opinion as to the proper time for striking centres. Some hold that the centre should be struck as soon as the arch is completed and the spandrel-filling is in place; while others contend that the mortar should be given time to harden. It is probably best to slacken the centres as soon as the keystone-course is in place, so as to bring all the joints under pressure. The length of time which should elapse before the centres are finally removed should vary with the kind of mortar employed and also with its amount. In brick and rubble arches a large proportion of the arch-ring consists of mortar, and if the centre is removed too soon the compression of this mortar might cause a serious or even dangerous deformation of the arch. Hence the centres of such arches should remain until the mortar has not only set, but has attained a considerable part of its ultimate strength.

Frequently the centres of bridge-arches are not removed for three or four months after the arch is completed, but usually the centres for the arches of tunnels, sewers, and culverts are removed as soon as the arch is turned and, say, half of the spandrel-filling is in place.

IV. CARPENTRY.

Inspection of Carpentry.

The inspection of carpentry requires the examination (1) of the material as to quality and dimensions; (2) of the workmanship in framing and placing it.

In the interior work of buildings there are many points to be watched, as the placing of centres for arches, the setting of lintels, wood bricks, furrings, grounds, etc., the framing and trimming around chimneys and openings in floors and roofs, the laying and nailing of flooring, the jointing and setting of the standing trim, etc.

The setting of window and door-frames requires precision on the part of the workman to make them plumb and securely fasten them, and the stuff used must be perfectly seasoned or the best workmanship will be thrown away.

The hanging of doors requires considerable care so that they may move freely without causing any injurious strains in the hinges. Door-locks and knobs require to be carefully fixed so they may work satisfactorily. The striking-plate is liable to be carelessly placed, being set either too high or too low or too far in the rebate, so that either the latch or the bolt will not enter the mortise intended for it. The "roses" or round plates screwed on opposite sides of the door, in which the stems of the knobs move, are rarely placed opposite to each other, so that the spindle, instead of being perpendicular to the door, is forced in an oblique direction, causing the knobs to bind and stick in turning. The knobs are frequently put on without the proper number of the thin washers which slip over the spindle for the purpose of filling out the space between the lock and the knobs on each side, and the latter are loose in consequence.

The setting of window-sashes requires care: nothing short of an actual trial of each sash of every window will serve to insure that all are as they should be.

Joints.

In executing all kinds of joints in timber the following general principles are to be adhered to as closely as may be practicable :

1. To cut the joints and arrange the fastenings so as to weaken the pieces of timber that they connect as little as possible.

2. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure it has to transmit.

3. To form and fit accurately every pair of surfaces that come in contact.

Beams are joined in the direction of their length by the operation called splicing, and the joints so formed are described as "lapping," "fishing," and "scarfing."

FISHING.—The ends of the pieces are butted together, and an iron or wooden plate or "fish-piece" is placed on each side and fastened by bolts passing through the beam.

The bolts should be placed checker-wise, so that the fish-plates and timbers are not cut through by more than one bolt-hole at any cross-section.

LAPPING is performed in a variety of ways, either by simply laying one beam over the other for a certain length and fastening them together with bolts or straps, or by halving and dovetailing the lapped portions.

SCARFING consists in cutting away equally from the ends, but on the opposite sides, of two pieces of timber for the purpose of connecting them lengthwise. The form given to the scarf is varied to suit the nature of the strain it has to bear.

Much ingenuity has been expended in devising scarfs of very intricate form, but the simplest are the best, as they are the easiest to fit accurately together.

HALVING is the simplest mode of joining timbers either lengthwise or crosswise. Half the thickness of each piece is cut out and the remaining portion of one just fits into the other, the upper and under surfaces of the pieces being flush. This is a common way of joining wall-plates and other timbers at an angle where there is no room to let the ends project so as to cross one another.

Bevelled halving: in this form the sides of the checks are splayed up and down.

Dovetail halving, so called from the shape of the pieces cut to

fit one another. They are objectionable in heavy timbers, because the wood shrinks considerably more across the grain than along it; the consequence is that they are easily drawn apart.

NOTCHING.—When one beam rests upon another or crosses it the upper one is notched down upon the lower one, either to bring its surface to a given level or to aid in keeping it in place. When the entire depth is cut from one beam it is termed "single notching." When each timber is cut it is called "double notching."

MORTISE AND TENON.—The *mortise* is a rectangular hole cut to receive the tenon; the sides of the mortise are called "cheeks." The *tenon* is formed by dividing the end of the stick of timber into three parts, and cutting out on both sides rectangular pieces each equal to the part left in the middle.

The tenon is usually made a little shorter than the depth of the mortise, so that the shoulders may bear firmly upon the timber in which the mortise is cut. The tenon is fastened in the mortise by a wooden pin. The pin-hole is usually placed at $\frac{1}{3}$ the length of the tenon from the shoulder, and is in diameter equal to $\frac{1}{4}$ the thickness of the tenon.

The hole in the tenon is made slightly larger (in the direction of the length of the tenon), so that the pin when driven shall draw the tenon tightly into the mortise and cause the shoulders to butt close and make neat work. Care is required in driving the pin so that it will not draw too much and thus tear out the bit of the tenon beyond the pin.

Double tenons are often used, but they should be avoided, as they weaken the timber into which they are framed, and both tenons seldom bear equally, so that a greater strain is thrown upon one of them than it is intended to support.

ABUTTING JOINT: A joint in which the fibres of one piece are perpendicular to those of the other.

BUTT-JOINT: A joint in which the pieces come square against each other endwise.

MITRE: A joint where two pieces are framed together, matched, and united upon a line bisecting the angle of junction.

Flooring.

Single flooring consists of a tier of joists running from one wall or partition to another without any intermediate support, and receiving the floor-boards on the upper edge, and the ceiling joists, if there be one, on the lower edge.

Double flooring consists of girders, sometimes called "binders, which support the floor-joists on their upper surface and the ceiling-joists on their lower surface, or in some cases they are left exposed to view and the ceiling-laths nailed directly to the floor-joists.

Hardwood floors are laid either straight-joint or folding, and are "edge-" or " secret-nailed." In the folding method two boards are laid and nailed at such a distance apart that the space is a little less than the aggregate width of 3, 4, or 5 boards These boards are then put in their place, and on account of the narrowness of the space left for them they rise like an arch and require to be forced down into place. Accordingly the boards do not rest solidly upon the boards below, nor can the floor be laid with any degree of accuracy. This method should be avoided in good work.

Straight-joint flooring is when every board is laid separately and blind- or edge nailed; any surface inequalities are reduced with the plane after the flooring is laid.

It is of great importance that the rough flooring should be of narrow boards (about 4 inches wide); if wide boards are used each one of them in shrinking will gather up, so to speak, a cluster of the narrow hardwood pieces above it and draw them tightly together, and will transfer its shrinkage to the joints immediately over it, so that in a short time there will be a considerable space between the two floors, and the strain thrown on the thin edge of the grooves will cause them to curl up or split.

It is usual before laying the finished flooring to spread upon the surface of the rough floor one, two, or three layers of felt paper to prevent air from passing through the joints and to deaden sound. Many and various qualities are manufactured, and care is required to see that the quality called for is furnished and that it is carefully and evenly laid.

PARTS OF FLOORS.

BAY: The portion of a framed floor included between two girders, or a girder and a wall.

A *case-bay* is the space between two girders.

A *tail bay* is formed of common joists, where one end of each is framed into or supported by a header or girder.

BINDING-JOIST: A joist whose ends rest upon the wall-plate and which supports the floor-joists above and the ceiling-joists below.

BRIDGING.—By "bridging" is meant a system of bracing floor-beams either by means of small struts set diagonally or by means of single boards set at right angles to the joists and fitting between them.

The ends of the bridging should be cut with exactly the same angle or bevel, so as to fit closely against the joist; they should range in a straight line, so that none of their stiffening effect be lost.

They should be fastened with two nails at each end, and care must be taken in nailing not to split them. To avoid this holes may be bored for the nails, or two small saw-cuts may be made to receive them.

Single bridging, consisting of a single strut between the joists, is frequently used. *Double bridging*, consisting of two struts crossing each other, is the stiffer, and should always be employed.

FLOOR-BEAMS.

JOISTS.—The horizontal beams supporting floors and ceilings Joists are usually spaced 12 inches centre to centre, and the ends rest upon wall-plates set in the walls.

Bevelling Ends of Joists.—"The ends of all wooden floor- and roof-beams, where they rest on brick walls, shall be cut to a bevel of three inches on their depth." (N. Y. B. L., 1896.)

Dimensions of Floor-beams.—"No wooden floor-beams nor wooden roof beams used in any building, other than a frame building, shall be of less thickness than 3 inches." (N. Y. B. L., 1896.)

Bearing of Beams.—"Every wooden beam, except header- and tail-beams, shall rest at one end 4 inches in the wall or upon a girder." (N. Y. B L., 1896)

Anchorage of Beams.—"Each tier of beams shall be anchored

to the side, front, rear, or party walls, at intervals of not more than six feet apart, with good strong wrought-iron anchors of not less than one and one-half inches by three eighths of an inch in size, well fastened to the side of the beams by two or more nails of wrought iron at least one fourth of an inch in diameter; where the beams are supported by girders, the girders shall be anchored to the walls and fastened to each other by suitable iron straps.

"The ends of beams resting upon girders shall be butted together end to end, and strapped by wrought-iron straps of the same size and distance apart, and in the same beam as the wall-anchors, and shall be fastened in the same manner as said wall-anchors, or they may lap each other at least twelve inches and be well spiked or bolted together where lapped.

"Every pier and wall, front or rear, shall be well anchored to the beams of each story, with the same size anchors as are required for side walls, which anchors shall hook over the same beam.

"Each tier of beams, front and rear, opposite each pier shall have hardwood or Georgia pine anchor-strips dovetailed into the beams diagonally, which strips shall cover at least four beams, and be one inch thick and four inches wide, but no such anchor-strips shall be let in within four feet of the centre line of the beams, or wooden strips shall be nailed on the top of the beams and kept in place until the floors are being laid." (N. Y. B. L., 1896.)

TRIMMING is the mode of framing around openings in floors, as where a chimney or stairway passes through.

TRIMMER-BEAMS: The trimmer- or carriage-beams are those which support the header-beams. The headers are mortised into the trimmer-beams, or may be supported by iron beam-hangers fastened to the trimmer-beams.

HEADER-BEAMS, or headers, are those which support the ends of the joist at one side of an opening.

TAIL-BEAMS: The beams or joists supported at each end by a header-beam.

RULES GOVERNING TRIMMING.—New York Building Laws, 1896:

"All wooden trimmer- and header-beams shall not be less than one inch thicker than the floor- or roof-beams on the same tier where the header is four feet or less in length; and where the header is more than four feet and not more than fifteen feet in

length the trimmer- and header-beams shall be at least double the thickness of the floor- or roof-beams, or shall each be made of two beams forming such thickness properly spiked or bolted together; and where the header is more than fifteen feet in length wrought-iron flitch-plates of proper thickness and depth shall be placed between two wooden beams similarly bolted together to and through the iron plates, or wrought-iron or rolled-steel beams of sufficient length may be used.

"Every wooden header or trimmer more than four feet long shall be hung in stirrup-irons of suitable thickness for the size of the timbers.

"All wooden beams shall be trimmed away from all flues, whether the same be a smoke-, air-, or any other flue. The trimmer-beam to be 8 inches from the inside face of a flue in a straight way, and 4 inches from the outside of a chimney-breast, and the header 2 inches from the outside face of the flue."

STRENGTH OF WOODEN BEAMS AND GIRDERS.—New York Building Laws, 1892–96:

"The breaking strength of wooden girders and beams shall be computed according to the formulæ in which the constants for transverse strains for central loads shall be as follows:

Hemlock	400
White pine	450
Spruce	450
Pitch or Georgia pine	550
Oak, American	550

For wooden beams and girders carrying a uniformly distributed load the constants will be doubled.

The *factors of safety* shall be as 1 to 4 for all beams, girders and other pieces subject to a transverse strain."

Roofs.

The framing of roofs is determined by the drawings, but the material and workmanship require to be closely scrutinized to see that the framing is properly executed, that the various bolts, straps, and other fastenings are properly placed. The roof-boarding is to be inspected for quality; it should be planed smooth on one side, with smooth straight edges, and be free from loose knots.

Parts of Roofs.

Angle rafter: A rafter at the hip of a roof receiving the heads of the *jack-rafters* or *cripple-studding.*

Arris-gutter: A V gutter fixed to the dripping-eaves of a roof.

Barge-board: A board beneath the gable holding the horizontal timbers. It is perforated, scalloped, or crenated to give it a light and ornamental appearance.

Collar-beam: A horizontal piece of timber connecting and bracing two opposite rafters.

Dragon-beam: A piece of timber to receive and support the foot of the hip-rafter.

Hammer-beam: A tie-beam connecting the feet of a pair of principal rafters, but having its middle portion removed, the ends of the gap being stayed by ribs springing from corbels below.

Eaves are the lower edges of the slopes of a roof.

Facia-board: A board fixed to the ends of the rafters and to which the gutter is attached.

Jack-rafter: One of the short rafters used in a hip-roof.

King-post: A main post beneath the crown or ridge of a roof-frame.

Purlin: A horizontal timber resting on a principal rafter.

Queen-post: The post in a roof-truss placed between the ridge and the eaves.

Rafter: One of the pieces of timber which follow the slope of a roof, and to which are attached the laths, boards, etc., which support the roof-covering.

Ridge: The upper horizontal edge or *comb* of a roof.

Ridge-beam: A beam at the upper edge of the rafters beneath the ridge.

STRUTS.—The posts or braces which run from the foot of the king-post to the centre of the rafters. Struts, being under compression, should be made of full length and of well-seasoned wood; otherwise upon shrinking they will allow the rafters to bend.

STRAINING-BEAM: A beam used in a queen-post roof to keep the heads of the queen-posts apart.

TIE-BEAM: The beam uniting the ends of a pair of principal rafters to prevent spreading.

TRIMMING: Wherever rafters come across any obstacle, such as a chimney, they must be trimmed in the same way as a floor.

WALL-PLATES are the timber laid on the tops of walls to carry the foot of roof-trusses, rafters, or ends of tie-beams. They are usually fastened to the wall by iron anchor-bolts.

At the angles of the walls the plates are halved or notched into one another, and well spiked together, and halved or scarfed wherever it is necessary to join them in the direction of their length; they should be in long pieces, so as to avoid this as much as possible.

Anchor-bolts should be built at every angle and at intervals of about ten feet. The bolts should be not less than one inch in diameter and three to four feet in length, with a square plate of iron at the lower end; they should be built in vertically and so set that the threaded end may project at least an inch above the top of the wall-plate. In setting this holes are bored for the bolts, and nuts with large washers are put in and screwed down firmly.

Stairs.

The workmanship on stairs must be closely examined to insure that the treads and risers are properly framed and secured, that the risers are of proper height, and that the carriages or strings are properly set. Stairs of varying height or out of level are both dangerous and unsightly. The wall-string must be carefully examined to see that it is securely fastened to the wall.

The securing of the handrail must be carefully looked after. It frequently happens that the mortising or dovetailing of the balusters is dispensed with, nails driven through the tread being substituted; this is a weak construction and should not be permitted. The securing of the end of a handrail which abuts against a wall is liable to be made in a shiftless manner unless specific directions are given for its proper securing.

The risers are united to the treads by joints, which may be tongued and grooved or rebated; in either case the joint is glued and blocked. The riser often has only its upper end tongued, the lower butting upon the tread below. This is not good construction. A common practice is to house the lower edge of the riser into the tread below. The tread is sometimes tongued into the riser, but this is not good construction.

The joints between the tread and riser should be strengthened by small triangular or square blocks glued in the angle. The inner ends of the treads where they rest upon the strings and also where they rest upon carriages should be supported by rough blocks or pieces of boards nailed to the strings and carriages. In some cases a board is notched out like a string and nailed along the side of the strings and carriages to answer for the rough blocks.

In some cases the upper edge of the risers is housed or dovetailed into the treads, and the back of the treads screwed up to the lower edge of the risers.

Parts of Stairs.

Baluster : Small pillar supporting a rail, as in a handrail.

Balustrade : A railing composed of balusters.

Carriage or String : One of the inclined pieces which supports the steps of stairs.

Flight is a continued series of steps without a landing.

Handrail : The moulded rail parallel nearly throughout its length to the general inclination of the stairs.

Landing is the flat resting-place at the top of any flight of stairs.

Newel : The principal post at the angles and foot of a stairs.

Nosing : The outer edge of the tread. In most cases it projects beyond the face of the riser and is rounded or ornamented by a moulding.

Rise : The vertical height between two treads.

Riser is the face or vertical portion of the step.

Strings.—The inclined pieces which support the steps of stairs. There are two classes—*open strings*, which are cut to show the outline of the steps; *close strings* have their upper and lower surfaces parallel, the steps being housed into them. The *wall string* is the string placed against the wall and fastened to it. The *outer string* is the one farthest from the wall. In wide stairs which require more support than is afforded by the strings

one or more rough strings called *carriages* are placed between the wall-string and the outer string.

TREAD : The horizontal upper surface of a step.

WINDER : The triangular or tapering steps required in turning a corner or going round a curve.

Doors.

HARDWOOD DOORS are usually veneered upon a core of well-seasoned pine to prevent warping. It is necessary to examine them upon delivery to see that the veneers are of the proper thickness and that the framing is properly executed.

PINE AND WHITE-WOOD DOORS intended for oil finish must be free from sap, knots, stain, pitch-streaks, and gum-spots, and finished with the grain.

PARTS OF DOORS.

PANELLED DOORS consist of a framework of narrow pieces of equal thickness put together with mortise-and-tenon-joints and grooved on the inside to receive the panels. The parts of doors are designated as follows :

STILES : The vertical rails or bars.

HANGING-STILE : The stile to which the hinges are attached.

SHUTTING-STILE : The stile on which the lock is placed.

RAILS : The horizontal bars of the framing, designated as the *top-rail, frieze-rail, middle* or *lock rail,* and *bottom rail.*

Panelled doors are distinguished by different technical names expressing their thickness, the number of panels they contain, and the kind of panelling.

PANELLING.—There are several forms of panels, known by technical names depending upon the manner in which they are respectively constructed and ornamented.

Flush Panels have their surfaces "flush" or in the same plane with the surface of the frame. A panel may be flush on one or both sides.

Square and Flat Panels are those in which the boards are of the same thickness throughout, thinner than the frame, sunk square below its surface, and not ornamented by beads or mouldings.

Moulded Square and Flat: When the edge of the panel, close to the framing, is ornamented by a moulding either "planted" or "stuck" on the inner edge of the frame.

Bead-flush panels have a bead all round close to the inner edge of the framing.

Bead and Butt: Framing in which the panels are flush and have beads stuck upon the two edges.

Bead and Quirk: A bead stuck on the edge of a piece of stuff flush with its surface.

Bead, Butt, and Square: Framing with bead and butt on one side and square on the other.

Solid Panels are those in which the panel is in one piece of the same thickness as the frame, and flush on both sides with its surface.

Chamfered Panel: The edges of the framing are chamfered.

Raised Panel has the surface nearly flush with the frame in the centre, but recessed back at the sides where it meets the frame.

Panelling is often enriched with mouldings of different designs; these are either "stuck" on the frame or "planted" in strips bradded on its inner side. Sometimes the panelling is required to have a different appearance on each side. It is then formed differently on the two sides and named accordingly.

Standing Finish or Trim.

ARCHITRAVES are mouldings fixed round the openings of doors and windows for ornament and also to conceal the joint between the frame and the plastering. The architrave should be of well-seasoned wood, should be blind-nailed, and should not be fixed in place until the plastering is completed and quite dry.

BASE-BOARD, SKIRTINGS.—A board from 6 to 18 inches in width placed round the base of the wall of a room, etc. The base-board may be plain or ornamented.

The base-boards should be tongued or dovetailed and mitred at the internal angles. They should be tongued wherever they are pieced in length. They should be so fastened to the wall as to allow for contraction and expansion without splitting.

The plastering behind the base-board should be carried down tight to the floor and no space left between the board and the wall.

The base-board should be put in place before the finished flooring is laid; in this way the base-board will extend below its sur-

face and thus can shrink without opening a crack between it and the floor.

LININGS are coverings of wood, usually some hard wood, so placed as to conceal or ornament portions of the interior of buildings. There are several varieties of linings, distinguished by technical names denoting the position in which they are fixed, as jamb- and soffit-linings to doors and windows.

All linings should be of narrow boards, ploughed, tongued, and grooved or rebated, so framed and nailed as to be free to expand and contract. Joints require careful attention in making, so that any shrinkage that may take place will not be visible.

MOULDINGS are of various designs and are used merely for ornament.

When a moulding is formed on the edge of a piece of timber in the substance of the wood itself it is said to be "stuck."

When it is on a separate slip of wood and attached to the piece it is to ornament it is said to be "laid in" or "planted."

In panelled work the mouldings are as a rule in separate slips, bradded or "planted" on to the inner edges of the frames, not on the panels, as the shrinkage of the latter would draw them away from the frame.

If, however, the moulding is "stuck" on the frame the groove for the panel should be deeper than the moulding; otherwise when the framing shrinks daylight will be seen through the open mitred corners of the moulding.

Machine-wrought mouldings frequently have slight indentations on the surface varying from a quarter to one third of an inch apart. These marks should be removed by sand-papering or if necessary by planing to prevent their showing after varnishing.

Care is required in splicing mouldings to see that the adjoining pieces are properly matched and that the joints do not come in prominent places.

The wall-moulding, i. e., strips of moulding placed round the outside of architraves and linings, must be securely and neatly fastened.

WAINSCOTING: A wooden facing about 3 feet high around the walls of rooms.

WAINSCOTING, FILLING BEHIND.—"When wood wainscoting is used, in any building hereafter erected, the surface of the wall or partition behind such wainscoting shall be plastered down to the floor-line, and any intervening space between the

said plastering and wainscot shall be filled in solid with incombustible material." (N. Y. Building Laws, 1896.)

Windows.

Windows consist of two parts: the *sash* or sashes which hold the glass, and the *frame* enclosing the sash.

The frame in which the sash slides is either *cased* or *solid.* The former has boxes at each side for the weights. The latter consists of strips fastened to the window-jambs.

A sash-casing consists of four pieces: the *pulley-piece* and *inside* and *outside* and *back lining.* The strips which form the sash-slides are the inside and outside *beads* and the parting-*bead.*

The parts of a sash-frame are the *head, sill, stool,* and *sides* or *casings.*

Frames require to be set plumb and securely fastened. If during the construction of the mason-work they get out of plumb they must be taken out and reset. After the frames are set pieces of boards should be nailed over the sills and if necessary on the sides to protect them from injury during the progress of the work.

The material used in the manufacture of the frames must be thoroughly seasoned and should be put together with paint made of 'inseed-oil and white lead.

The top of the frame is sometimes covered with water-proof felt or a flashing of tin so as to prevent water from getting into the frames.

SASHES.—The sashes are constructed like ordinary framing. The upright sides are the stiles, and the transverse or horizontal ones which are tenoned into the ends of the stiles are the rails, and the interior pieces are the bars. If the bars are mitred at the joints they require dowels in the ends to act as tenons.

The upper posts of the sashes have grooves taken out of their sides about $\frac{1}{2}$ inch square and extending downwards about 6 inches from the top, with a hole bored below it for 3 or 4 inches, which terminates in a large hole sunk in the side of the stile to receive the ends of the *sash-lines,* which are secured by a knot and nailed; these pass over iron or brass pulleys fixed in slots near the top of the pulley-stiles, and are attached to the weights which counterbalance the sashes.

The weights are of cast iron, either circular or rectangular in section. In selecting them the sash is weighed and two weights are chosen which just balance the sash.

The weights are introduced through a rectangular hole formed in the pulley-stile. This hole is called the *pocket* and is covered by a flush cover, or *pocket-piece.* The upper end of this cover is usually rebated and undercut, and the lower end bevelled to fit snugly into the pulley-stile. There are various ways of making the joint, but in whatever manner it is made the ends of the cover should be fastened with brass screws.

Terms used in Carpentry.

ANGLE-STAFF : A strip of wood fixed to the vertical angle of a wall flush with the plastering of the two planes. It is designed as a substitute for plaster in a situation so much exposed.

A *round staff* is known as an *angle bead.*

ANGLE-TIE : A brace in the interior angle of a wooden frame securing two side-pieces together and occupying thereto the position of a hypotenuse.

ASHLARING : Short upright pieces between the floor-beams and rafters in garrets for nailing the laths to.

ASTRAGAL : (*a*) A small moulding of a semicircular section with a fillet beneath it ; (*b*) one of the rabbeted bars which hold the panes of glass in a window.

BARGE-COUPLE : A beam mortised into another to strengthen the structure.

BATTEN.—A strip of wood from ½ to 2½ inches thick, and from 1 to 7 inches wide.

A cleat or bar nailed transversely on a structure of jointed planks, such as a door or shutter, to prevent warping and to preserve the relative position of the parts.

A strip nailed to the rafters to which slates, etc., are nailed.

A batten door is formed of planks laid side by side, and secured together by battens fastened across them without any exterior framing.

BEAD : A small convex moulding of semicircular section ; the circular portion is the bead, and the indentation on the side is called a *quirk.*

BEAM.—A straight stick of timber, usually occupying a relatively horizontal position in a structure. Specific denominations have been conferred upon beams in framed structures of wood, as :

Straining-beam : One used in a truss or frame to confine principal parts in place.

Truss-beam : The principal horizontal timbers of a truss, called the top and bottom chords, and from which proceed the stays and braces which hold and confer rigidity upon the frame.

Arched Beam : A beam bent, cut, or built into an arched form.

Built Beam : One made up of several parts scarfed or strapped together.

Kerfed Beam : A beam whose under side has a number of transverse kerfs or saw-cuts penetrating to a certain depth, so as to enable it to be bent.

BEARD : The sharp edge of a board.

BEARER : A beam employed to carry other portions, as joists or short pieces to support gutters.

BEVELLING : The sloping of an arris ; removing the square edge.

BIRD'S-MOUTH : The notch at the foot of a rafter where it rests upon or against the plate.

BLOCK.—A square or triangular piece of wood fitted in the re-entering angle formed by the meeting of two pieces of board. The blocks are glued at the rear and strengthen the joint.

BOARD.—A sawed piece of wood, relatively broad, long and thin, exceeding 4½ inches in width and less than 2½ inches in thickness. The term plank is applied to a grade thicker than boards, though the two terms are often used indiscriminately.

1. *Clapboard*, a rived slab of wood.
2. *Feather-edged*, one edge thinner than the other.
3. *Listed*, the sap-wood removed.
4. *Edge-shot*, the edge planed true.
5. *Wrought*, planed on one side.
6. *Matched*, tongued and grooved.
7. *Jointed*, lined and edge-planed so as to come together correctly.

BOLSTER : A horizontal cap-piece laid upon the top of a post or pillar to shorten the bearing of the beam or string-piece above.

BOX-FRAME : A casing behind a window-jamb for counterbalance-weights.

BRACE : A diagonal stay or scantling connecting the horizontal and vertical members of a truss or frame.

BREAST-SUMMER : A beam inserted flush with the house-front which it supports, and resting at its ends upon the walls and at intermediate points upon pillars or columns.

BRIDGE-BOARD: A notched board to which the *treads* and *risers* of a stair are fastened.

CAP: The timber placed on the top of piles or posts.

CHAMFER.—A bevel or slope forward by cutting off the square edge of a board or beam. *Stop-chamfer* is one in which the chamfer is not carried to the extremity of the timber, but stopped and sloped or curved up at the end till it dies away again into the square angle.

CLAPBOARD.—A term irregularly used. It means:

1. A weather-board on the side of a house, laid on lapping over the one below it.

2. A roofing-board larger than a shingle, and not usually shaved. A common size is a riven board 48 inches long and 8 inches broad. They are rived in the direction of the medullary rays, and the edge toward the heart is the thinner of the two.

CLEAT: A strip of wood secured to another to strengthen it.

CORBEL: A bolster; a wooden supporting-piece or bracket.

CREST: The ridge of a roof.

DIAGONALS: Boards, etc., nailed on diagonally.

DADO: A rectangular groove formed in a board with a tool called a dado-plane (see Housing).

DOVETAIL: A flaring tenon adapted to fit into a mortise with receding sides to prevent withdrawal in the direction of the tension it will be exposed to in the structure.

DOWEL: A pin used to connect adjacent pieces, penetrating a part of its length into each piece at right angles to the plane of junction.

DRAW-BORE.—A hole so made through a tenon and mortise that the pin will draw up the shoulder to the abutment. The hole through the tenon is bored at a distance from the shoulder less than the thickness of the cheeks measured between the hole through the mortise and the face of the abutment against which the shoulder is drawn.

FLATTED: Timber that is hewn or sawn on two opposite sides only.

FURRINGS are strips of wood nailed to joists, rafters, or walls to bring their surface to a uniform level before placing the laths for plastering.

GAIN: A notch made in the side of a timber to receive another.

HOUSING consists in letting the whole end of one piece of timber for a short distance into another. The groove or recess

formed in one piece is called the housing, and one piece is said to be housed or dadoed into the other.

LINTELS : Short beams over the heads of doors and windows for supporting the superincumbent wall.

MATCHED BOARDING : Boards planed so as to form a close joint; also applied to boards provided with a tongue and groove on opposite sides.

PLATE.—A beam on a wall or elsewhere to support other portions of a structure. *Sill-plates* are timbers laid upon foundation-walls. *Floor-plates* or interties are timbers which are framed into the studding, for the floor-beams to rest upon. *Wall-plates* are the timbers placed on top of the wall to support the ends of the roof.

PLOUGH GROOVE : A recess formed by a tool called a plough (see Dado).

REBATE OR RABBET : A half groove along the edge of a board or moulding forming a longitudinal recess.

SCANTLING : Lumber under 6 inches square.

SCARF : A joint uniting two pieces endwise.

SEASONED : Dried lumber.

SPLICE : A scarf-joint by which timbers are united for the purpose of lengthening them.

SCRIBING : Cutting the edge of a board to fit an irregular surface.

SPLINE : A strip of wood or iron used instead of a tongue for driving in the grooves of planks (used in sheet piling).

SECRET- OR BLIND-NAILED : Nails driven so that the heads are concealed, as in flooring nailed through the tongue.

SHOT : The edges of a board are said to be shot when it is planed perfectly straight.

STRINGER : A horizontal beam.

STUD : The vertical piece in a stud partition.

STILES : The upright pieces of a door- or shutter-frame.

SILL.—A sill in framing is a timber which is laid across a tier of beams in order to receive the feet of the partition-studs. *Mud-sill*, the bottom timber in a trestle-bent.

TONGUE : A fin on the edge of a board adapted to fit into a groove on an adjacent board; called a tongue-and-groove joint.

TONGUE, SPLINE, OR FEATHER : A detached strip of wood or iron used instead of the tongue formed on the side of a plank for driving in the grooves formed in the plank (used chiefly in sheet-piling).

Transom : A horizontal cross-bar or mullion separating a door from a window over it; also applied to the window formed over a door.

Upright : A pillar or post in a frame or structure.

Veneered : Covered by a thin sheeting of ornamental wood.

Wash-boards : The boards surrounding a room at the floor to a heighth of 6 to 18 inches (see Base-board and Skirtings).

Weather-boarding : An outer covering of boards, which are generally placed horizontally, so that the higher board overlaps to one below; sometimes they are placed vertically with battens over the joints.

Wood Bricks are pieces of wood of the same thickness as bricks built into the walls as the work progresses for nailing the casings of doors, windows, etc., to.

V. IRON- AND STEEL-WORK.

Erection of Iron and Steel Structures.

In erecting iron or steel structures care must be exercised to protect the material from injury by falls or heavy shocks.

In bringing the several parts together for bolting or riveting the use of heavy mauls for driving should not be allowed. Wooden mauls should be used. Parts must not be forced together, and any failure of members to come together properly must be noted and reported daily to the engineer or architect. If any difficulty arises which cannot be overcome by the ordinary appliances at hand it must be reported to the engineer before any radical measures are used to meet it.

Special care must be exercised to keep columns plumb and the entire work in line. Probably the worst practice in the erection of architectural ironwork is the very common use of shims in the joints between the successive column-sections, thus concentrating the loads on the opposite sides of the cross-section. The columns are usually kept plumb in this manner, but the practice is extremely vicious and should not be allowed. If the faces of the ends of the columns are properly planed or milled off, and the base-plate set level, the use of shims will not be necessary. The greatest difficulty is in setting the base-plate in a truly horizontal plane. The ordinary carpenter's level is not sufficiently delicate; an engineer's level should be used.

During wet weather the ironwork should be protected by water-proof canvas, tarred paper, or other material to prevent water from lodging in the concealed parts of the work.

COLUMN-BEARINGS, BED- AND CAP-PLATES.—N. Y. Building Laws, 1896:

"All cast-iron, wrought-iron, and steel columns shall have their bearings faced smooth, and at right angles to the axis of the column; and when one column rests upon another column they shall be securely bolted together.

"All cast-iron, wrought-iron, or rolled-steel columns shall be made true and smooth at both ends, and shall rest on iron or steel

bed-plates, and have iron or steel cap-plates, which shall also be made true.

"In columns of rolled iron or steel the different parts shall be riveted to each other, and shall be united by riveted connections to the beams and girders resting upon them.

"In cast-iron columns each successive column shall be bolted to the one below it by at least three ⅝-in. bolts, and the beams and girders shall be bolted to the columns."

SETTING BEAMS PARALLEL.—In placing beams which are to support floor arches, too great care cannot be exercised to have them all parallel, especially where one or both ends rest on brick-work. Beams placed out of parallel make it very expensive to construct the arches, and cause injury by the consequent defective form and jointing of the arches. In tile arches it causes cutting of tiles, which is injurious, and should not be done.

Setting and Connecting Beams.

(N. Y. Building Laws, 1896.)

LENGTH OF BEARING ON WALLS.—"All wrought-iron or rolled-steel beams 8 inches deep and under shall have bearings equal to their depth; 9 to 12 inch beams shall have a bearing of 10 inches, and all beams more than 12 inches in depth shall have bearings of not less than 12 inches.

"Where beams rest on iron supports, and are properly tied to the same, no greater bearings shall be required than one-third of the depth of the beam.

"Under the ends of all iron or steel beams where they rest on the walls a stone or cast-iron template shall be built into the walls. Said template shall be eight inches wide in twelve inch walls, and in all walls of greater thickness said template shall be twelve inches wide, and such templates, if of stone, shall not be in any case less than two and one-half inches in thickness, and no template shall be less than twelve inches long."

BEAM CONNECTIONS.—"All iron or steel trimmed beams, headers, and tail-beams shall be suitably framed and connected together.

"Where beams are framed into headers, the angle-irons which are bolted to the tail-beams shall have at least two bolts for all beams over seven inches in depth, and three bolts for all beams twelve inches and over in depth, and these bolts shall not be less

than three-fourths of an inch in diameter. Each one of such angles or knees, when bolted to girders, shall have the same number of bolts as stated for the other leg. The angle-iron in no case shall be less in thickness than the header or trimmer to which it is bolted, and the width of the angle in no case shall be less than one-third the depth of the beam, excepting that no angle-knee shall be less than two and one-half inches wide, nor require to be more than six inches wide."

ARRANGEMENT AND DEFLECTION OF FLOOR-BEAMS.—New York Building Laws, 1896: "Iron or steel floor-beams shall be so arranged as to the spacing and length of beams that the load to be supported by them, together with the weight of the materials used in the construction of said floors, shall not cause a deflection of the said beams of more than $\frac{1}{30}$ of an inch per linear foot of span, and they shall be tied together at intervals of not more than eight times the depth of the beam."

ANCHORING BEAMS.—"The iron girders, columns, beams, trusses, and all other ironwork of all floors and roofs shall be strapped, bolted, anchored, and connected together, and to walls, in a strong and substantial manner." (New York Building Laws, 1896.)

Anchor-straps should be bolted to the end of each girder and to the wall end of every alternate joist, binding the walls firmly from falling outwards in the event of fire or other accident.

Lintels and Girders of Iron and Steel.

(New York Building Laws, 1896.)

LENGTH OF BEARINGS.—New York Building Laws, 1896: "All iron or steel lintels shall have bearings proportionate to the weight to be imposed thereon, but no lintel used to span any opening more than 10 feet in width shall have a bearing less than 12 inches at each end if resting on a wall, but if resting on an iron post such lintel shall have a bearing of at least 6 inches at each end by the thickness of the wall to be supported.

"When the lintels are supported at the ends by brick walls or piers they shall rest upon cut granite or bluestone blocks at least 12 inches thick, or upon cast-iron plates of equal strength by the full size of the bearings. In case the opening is less than 12 feet the stone blocks may be 6 inches in thickness, or cast-iron plates of equal strength by the full size of the bearings may be used.

This requirement shall not apply to cast-iron lintels used at the back of stone lintels over openings not exceeding 6 feet in width.

"In all cases where the girde rcarries a wall and rests on brick piers or walls, the bearings shall be sufficient to support the weight above with safety."

SIZE OF IRON AND STEEL LINTELS AND GIRDERS.—New York Building Laws, 1896: "No cast-iron lintel or beam shall be less than $\frac{3}{4}$ of an inch in thickness in any of its parts.

"Iron beams or girders used to span openings more than 16 feet in width, upon which walls rest or upon which floor-beams are carried, shall be of wrought iron or rolled steel and of sufficient strength; or cast-iron arch-girders may be used having a rise of not less than one inch to each foot of span between bearings, with one or more wrought-iron tie-rods of sufficient strength to resist the thrusts, well fastened at each end of the girder.

"All lintels or girders placed over any opening in the front, rear, or side of a building, or returned over a corner opening, when supported by brick or stone piers or iron columns, shall be of iron or steel, and of the full breadth of the wall supported."

Fire-proof Floors.

The term "fire-proof floor" is applied to floors constructed of fire-proof material supported on or between iron or steel beams or girders, or fire-proof walls, and entirely protecting the metal-work from the action of fire.

The materials employed are ordinary building brick, hollow porous tile, hollow dense tile, thin plates of dense tile, iron in various forms imbedded in concrete composed of Portland cement and either cinders, broken stone, brick or tile; and also compositions made with plaster of Paris as a cementing material.

Brick Arches.—These usually consist of a single 4-inch course of brick with a rise at the centre of 3 or 4 inches (the preferable rise is not less than one-tenth of the span), resting either on the lower flanges of the I beams or on cast-iron or rolled-steel skew-backs fastened to the beams. If the floor is designed for very heavy loads several courses of brick are used.

For first-class work the bricks should be ground to the taper of the arch, and be laid in place with as little mortar as possible.

The space above the arch is usually filled in with concrete, in

which are imbedded wooden strips 3 $\times$ 4 inches for securing the wooden flooring.

The horizontal thrust of the arches is provided for by the use of tie-rods from ⅝ to 1 inch in diameter, spaced along the centre line of the beams or a little below, at regular intervals of from 5 to 7 feet. The last rod is securely anchored to the wall, where an angle, channel, or simply a wall-plate is used to support the arch and to properly distribute the load upon the wall.

In many cases where the arches abut against each side of the beam tie-rods are omitted, but it is always safer to use them, as the outside "bay" of the floor might be pushed off sidewise if the whole were not tied together; also, if one of the arches should fall or break through, the rods would keep the other arches in place.

FORMULA FOR TIE-RODS FOR BEAMS SUPPORTING BRICK ARCHES.—The horizontal thrust of brick is as follows:

$$\text{Pressure in pounds per lineal foot of arch} = \frac{1.5\ WS^2}{R}.$$

W = load in pounds per square foot.
S = span of arch in feet.
R = rise of arch in inches.

Place the tie-rods as low through the webs of the beams as possible and spaced so that the pressure of the arches as obtained by the above formula will not produce a greater stress than 15,000 lbs. per square inch of the least section of the bolt.

The beams supporting flat tile arches should invariably be bolted together with ¾-inch tie-rods, placed as near the bottom flange as practicable and drawn up tightly by nut and thread; when so placed the floors are much stiffer and there is less liability to cracks in ceilings than when the tie-rods are placed in the centre of the beams. The tie-rods should be spaced from 5 to 7 feet, centre to centre.

The formula for the diameter of the tie-rod for any floor is

$$D^2 = \frac{W \times S}{62832r}.$$

D^2 = diameter of rod in inches.
W = weight of floor and superimposed load resting on the arch, halfway between the tie-rods on each side, in pounds.
S = span of arch in feet.
r = rise of arch in feet.

Hollow Tile.—These are furnished by the manufacturers in a great variety of patterns and of a strength to meet the desired requirements. Two general forms of construction are used, the segmental and the "flat" arch. The flat arch usually has bevel joints; radial joints are seldom used. Two methods of constructing the flat arch are practised: one in which the blocks abut end to end continuously between the beams, and one in which they lie side by side, with broken joints between the beams. In the end system it is not usual to have the blocks in one row break joints with those in another, as it entails extra expense in setting. When it is done the strength of the floor is much increased.

When dense tile are used they are backed up with concrete in which is imbedded the wooden strips for attaching the flooring. These strips should be of sound, seasoned wood, 2 inches thick by 2 inches wide on top, bevelled on each side to 4 inches wide on the bottom, placed about 16 inches between centres. The concrete should be firmly bedded beneath and against each side. When the finished floor is to be marble or tile the wooden strips are omitted.

When porous tile is used they are generally made the full depth of the beam, the concrete backing being dispensed with, as they receive nails as readily as wood.

LAYING TILE.—In laying tile a mortar composed of lime mixed with coarse-screened sand, in proportions of one to four, is used. A mortar-joint exceeding $\frac{1}{8}$ inch in thickness should not be permitted.

The best form of centring for flat arches is that in which T bolts are used, and double 2x6 inch sound lumber centre-pieces below, placed midway between the beams and extending parallel with them, and like centre-pieces above, crossing the beams. The planks on which tiles are laid should be 2-inch, dressed on one side to uniform thickness, and should lie on lower centres, at right angles to the beams and placed close together. The soffit-tile should be a separate key-shaped piece, of same width as the beam, and laid directly under the beam on the planking, after which the centring is tightened by screwing down the nuts on the T bolts, until the soffit-tile are hard against the beams and the planking has a crown not exceeding $\frac{1}{4}$ inch in spans of six feet.

The tiles should be laid "shoved," with close joints; and keys should fit close.

The centres should remain in place from 12 to 36 hours, accord-

ing to conditions of weather, depth of tiling, and kind of mortar used.

When centres are "struck," the ceiling should be straight, even, and free from open joints, crevices, and cracks.

The laying of flat tile arches in winter weather without roof protection should not be practised in climates where frequent rain and snow storms are followed by hard freezing and thawing, as the mortar-joints are liable to be weakened or ruptured, resulting in more or less deflection of the arches.

TABLE 59.

WEIGHT AND SPANS OF FLAT HOLLOW DENSE-TILE ARCHES.

Depth of Arch.	Span between Beams.	Weight per Square Ft.
Inches.		Pounds.
6	3.6" to 4.0"	29
7	4.0 " 4.6	32
8	4.6 " 5.6	35
9	5.0 " 5.9	37
10	5.9 " 6.6	41
12	6.6 " 7.6	48

TABLE 60.

WEIGHTS AND SPANS OF FLAT HOLLOW POROUS-TILE ARCHES.

Depth of Arch.	Span between Beams.	Weight per Square Ft.
Inches.		Pounds.
6	3.0" to 5.0"	21
7	3 6 " 5.6	24
8	4.0 " 6.0	27
9	4.6 " 6.6	30
10	5.0 " 7.0	33
12	6.0 " 8.0	37
15	7.6 " 10.0	43

Six-inch hollow tile of either kind for segmental arches weigh from 26 to 36 lbs. per square foot.

STRENGTH OF FLAT-TILE ARCHES.—Flat arches should in all cases be capable of sustaining without serious deflection, after being set in place, an equally distributed load of 500 pounds per square foot of surface.

Tests for Tile Floors.—Each arch shall be subjected to a test of a moving load consisting of a roller weighing 1000 pounds to each lineal foot, and applied 48 hours after the centres have been struck and before the concrete has been filled in.

In addition to the rolling test, the arches after being set in place 72 hours shall be subjected to a dropping test made in the following manner: Before the concrete is applied on the arches a bed of sand two inches thick shall be spread loosely over the top of the arches, and a wooden block or timber weighing 200 pounds shall be dropped thereon from a height of ten feet. If the arches withstand this impact for three continuous blows without breaking through, the test shall be considered satisfactory, and the floor arches be accepted.

Concrete Floors.—There are several systems of constructing concrete floors. In some the concrete is supported on corrugated or other special forms of sheet iron; in others the concrete is employed as an arch, being made self-supporting by imbedding in it iron or steel rods and bars of various forms. Metal lath, and wire netting of various forms. Wire cables are also used.

The various systems of concrete and composition flooring are in nearly all cases covered by patent, and full information concerning them can be obtained from the manufacturers.

Construction of Fireproof Floors.—New York Building Laws, 1896: "All brick or stone arches placed between iron or steel floor-beams shall be at least four inches thick and have a rise of at least one and a quarter inches to each foot of span between beams. Arches of over five feet span shall be properly increased in thickness, as required by the superintendent of buildings, or the space between the beams may be filled in with sectional hollow brick of hard-burned clay, porous terra-cotta, or some equally good fire-proof material, having a depth of not less than one and one-quarter inches to each foot of span, a variable distance being allowed of not over 6 inches in the span between beams. The said brick arches shall be laid to a line on the centres, with close joints, and the bricks shall be well wet, and the joints filled with cement mortar in proportions of not more than 2 of sand to 1 of cement by measure. The arches shall be well grouted and pinned or chinked with slate, and keyed.

"The bottom flanges of all wrought-iron or rolled-steel floor-beams, and all exposed portions of such beams below the abutments of the floor-arches, shall be entirely incased with hard-burnt

clay or porous terra-cotta; or with wire metal lath properly secured and plastered on the under side. The exposed sides and bottom plates or flanges of wrought iron, or rolled-steel girders supporting iron, steel, or wooden floor-beams, or supporting floor-arches or floors, shall be entirely incased in the same manner."

VI. Roofing.

Inspection of Roofing.

The inspection of roofing requires considerable care because of the difficulty of detecting defects after the work is done until attention is called to them by damp walls or damaged ceilings.

The first points to be examined are the quality and dimensions of the materials ; 2d, the quality of the workmanship in cutting, fitting, and placing the roof-frame, the laying of the sheathing, purlins, etc., and the laying, fastening, etc., of the roof-covering, and the forming of the flashings, gutters, connecting of leaders, etc.

In slating, tiling, and shingling an important point is the sufficiency of the bond or lap. These materials are said to be laid so many inches to the weather, meaning the amount of the exposed portions. By increasing the length of the exposed portion, thus reducing the lap, a less number of courses will be required to cover the roof.

The sheathing-boards should be sound, free from large knots, and well seasoned, laid with close joints in regular courses diagonally across the rafters and nailed with two nails to each bearing. All joints should be made in the centre of bearings, the ends of the boards being cut to the required angle.

The sheathing-boards are usually covered with asphalted felt, tarred felt, or paper. In laying this material the joints should have a lap of 2 inches and be nailed at intervals of 2 or 3 inches with $\frac{7}{8}$-in. roofing-nails. One pound of nails should be allowed for each 100 square feet of roof. Dry or rosin-sized felt should not be used on roofs.

On the completion of the roofing all accumulations of rubbish in the gutters must be cleared out, and nothing left to impede the flow of the water to the leaders.

Tin Roofing.—For laying on the roof the sheets of tin are joined together by having the edges bent in the form of a hook, called both "single" and "double" groove or lock ; the sheets are hooked together, then hammered flat, and then soldered. Sev-

eral sheets are thus joined and formed into a roll. The rolls are carried to the roof and spread out; their sides are joined by forming a single groove on each edge, flattened down, and soldered.

In soldering the joints, rosin as a flux is generally preferred, although some roofers recommend the use of dilute chloride of zinc.

For a steep roof, tin should be put on with a standing groove and with the cross-seams double-locked and soldered. The tin should be laid with the smallest dimension for the width, as it makes the roof stronger, and allows a greater amount of expansion and contraction; but it is much cheaper to lay them the other way, as less cleats, solder, nails, and labor are required. For flat roofs with flat seams it does not make any difference which way the plates are laid, as the entire roof is practically a solid sheet.

A very common and cheaper method for steep roofs is to double-lock both the vertical and cross seams, and fill the joints with white lead instead of soldering; but the other method is much the best.

To hold the tin securely to the sheathing-boards, pieces of tin three or four inches long by two inches wide, called "cleats," are nailed to the boards at about every eighteen inches along the joints of the rolls that are to be united, and are bent over with a double groove. They should be nailed with a fourpenny slating-nail, which has a broader head than common nails; and as the nails are not exposed to the weather, they may be of plain iron. The nails should not be driven through the roofing-plates.

The under side of the tin should be painted before laying on the roof

One or more layers of felt paper should be placed under the tin, to serve as a cushion, and also to deaden the noise produced by the rain striking the tin.

Before painting all grease and rosin should be thoroughly scraped and cleaned off.

The tin used for gutters and flashings should be of the heaviest coated or dipped plates and should always be of IX thickness.

Roofing-tiles are thin slabs of baked clay.

Plain roofing-tiles are usually made ⅝ of an inch in thickness, 10½ inches long, and 6¼ inches wide. They weigh from 2 to 2½ pounds each, and expose one half to the weather. Plain tiles are also made with grooves and fillets on the edges, so that they are laid without overlapping very far.

Pan-tiles have a wavy surface, lapping under and being over-

lapped by the adjacent tiles of the same course. They are made 14¼ × 10½ inches, expose 10 inches to the weather, and weigh from 5 to 5½ pounds each.

Tiles are laid in the same manner as slates, fastened with two nails to each tile.

Crown-, ridge-, hip-, and valley-tiles are semi-cylindrical, or segments of cylinders, used for the purpose indicated by the name.

Tiles should be well burned and be free from fire-checks, cracks, blisters, and flaws.

Shingles.—The principal requisites of good shingles are freedom from knots, cross-grain, and an approximation to uniform width. The wood usually employed for shingles is cedar, cypress, and Michigan pine (spruce is occasionally used; but makes shingles of a very inferior quality).

Shingles are usually laid in three thicknesses, except for an inch or two at the upper ends, where there are four. They are nailed to sawed shingling-laths of oak, spruce, or pine, about 16 feet long, 2½ inches wide, and 1 inch thick, placed in horizontal rows about 8½ inches apart. Two nails are used for each shingle, near its upper end; they should not be of less size than 400 to a pound. Wrought nails are the best; cut nails are apt to break off by the warping of the shingles.

Shingles are usually 27 inches long by from 6 to 7 inches wide, about ½ inch thick at the upper end, and about ⅛ inch at the lower end or butt, and are laid in courses exposing from 4 to 6 inches to the weather—One thousand shingles require about 5 lbs. of nails.

TABLE 61.

NUMBER AND WEIGHT OF SHINGLES (PINE) PER SQUARE.

Number of Inches exposed to Weather.	Number of Shingles per Square.*	Weight per Square. Pounds.
4	900	216
4½	800	192
5	720	173
5½	655	157
6	600	144

* For hip-roofs add 5 per cent.

Slates are laid either on a broad sheathing (rough or tongued and grooved) covered with tarred paper or felt, or on roofing-

laths, 2 to 3 inches wide and from 1 to 1¼ inches thick, nailed to the rafters at distances apart to suit the gauge of the slates.

The slates are fastened with two 3d. or 4d. nails, one near each upper corner. Copper, composition, tinned, or galvanized nails should be used. Plain iron nails are frequently used; they are speedily weakened by rust, break, and allow the slates to be blown off. When used they should be heated and immersed in boiled linseed-oil as a partial preservative from rust.

On iron roofs slates are often placed directly on small iron purlins spaced at suitable distance to receive them. There the slates are fastened with wire passed through the holes in the slate and twisted around the purlins. Special forms of fasteners are also used instead of wire.

The gauge of a slate is the portion exposed to the weather. The slater estimates the length of the slate from the nail-hole to the tail, discarding the narrow strip between the nail-hole and the head. In order that the showing lower edge of the slates shall when laid form regular straight lines along the roof the nail-holes are made at equal distances from the lower edges.

As the slates do not lie exactly parallel to the boarding, and consequently do not lie flat upon it, those at the lower edge would be easily broken. To prevent this a *tilting-strip* (a lath with its upper side planed to a bevel corresponding to the slope of the roof is first nailed at the eaves for the tail of the lowest course of slates to rest on.

The upper side of a slate is called its *back*, the lower one its *bed*.

The area of roof covered by a slate of given dimensions is ascertained by multiplying the gauge by the width of the slate in inches.

Slates should be sorted in sizes when they are not all of one size, and the smallest placed near the ridge.

The top course of slate on the ridge, and the slates for two to four feet from all gutters, and one foot each way from all valleys and hips, should be bedded in Portland-cement paste.

In laying slates the great object to be attained is that the bottom edge or "tail" of every slate should fit as closely as possible to the backs of those below it. The vertical joints between the slates should be as close as possible, and each should fall on the central line of the slate below.

In good slating the vertical joints of the alternate courses should range in straight lines from ridge to eaves, and the tails of the slates should be in perfectly horizontal lines.

CHARACTERISTICS OF GOOD SLATES.—A good slate should be both hard and tough.

Softness or liability to abrasion does not always indicate inferior roofing-slate. A moderate degree of softness indicates good weathering qualities.

If it is too soft, it will absorb moisture, the nail-holes will become enlarged, and the slate will become loose.

If it be brittle, it will break in the process of squaring and holing.

A good slate should give a sharp metallic ring when struck with the knuckles. It should not splinter under the slater's axe, should be easily "holed" without danger of fracture, and should not be tender or friable at the edges.

A good roofing-slate should not absorb water to any perceptible extent.

A common and easily applied test for roofing-slate is to place one on edge to half its depth in water, and if in, say, 12 hours the line of absorbed water approaches the top of the slate, it should be rejected. If it does not rise beyond one-eighth of an inch, the slate may be considered as practically nonabsorbent.

Another method is to weigh a well-dried slate, and after soaking it for 12 hours in water to weigh again; the difference in weight will show the quantity of water absorbed.

A good slate after 12 hours' soaking in water should not have absorbed more than $\frac{1}{200}$ part of its weight.

As a test of the weathering quality it is recommended to breathe on the slate. If a clayey odor be strongly emitted, it is inferred that the slate will not "weather" well.

NOTES ON SLATES.—(Northampton County (Pa.) Slate.)—The best slates are called "No. 1 stock." Those with one ribbon crossing them are "No. 1 Rib," and those with two ribbons "No. 2 Rib."

Ribbons are seams which traverse the slate in approximately parallel directions, and which differ in color and composition from the slates proper. In the upper beds the ribbons are soft and of inferior quality to the slate proper; in the lower they are often harder than the slates.

Slates containing soft ribbons are inferior, and should not be used in good work.

The soft slates weigh about 173 lbs. per cubic foot, and the best qualities have a modulus of rupture of from 7000 to 10,000 lbs. per square inch.

The stronger the slate the greater is its toughness and softness and the less its porosity and corrodibility.

The strongest slate stands the weather best, so that a bending test affords an excellent index of all its properties.

The strongest and best slate has the highest percentage of silicates of iron and aluminum, but is not necessarily the lowest in carbonates of lime and magnesia.

Chemical analyses give only imperfect conclusions regarding either durability or physical properties.

Bending tests should be required by the specifications.

Slates are made in numerous sizes, varying from 6 × 12 to 16 × 26 inches. In proper roofing a triple lap of 3 inches is allowed; thus for a 24-inch slate $10\frac{1}{2}$ inches of each slate are uncovered, $10\frac{1}{2}$ inches are covered by one thickness, and 3 inches by two thicknesses.

The amount of slate required to cover a space 10 × 10 feet is called a square.

TABLE 62.

SLATE.

DIMENSIONS AND NUMBER PER SQUARE.

Dimensions. Inches.	Number per Square.	Dimensions. Inches.	Number per Square.
6 × 12	533	12 × 18	160
7 × 12	457	10 × 20	169
8 × 12	400	11 × 20	154
9 × 12	355	12 × 20	141
7 × 14	374	14 × 20	121
8 × 14	327	16 × 20	137
9 × 14	291	12 × 22	126
10 × 14	261	14 × 22	108
8 × 16	277	12 × 24	114
9 × 16	246	14 × 24	98
10 × 16	221	16 × 24	86
9 × 18	213	14 × 26	89
10 × 18	192	16 × 26	78

Thickness $\frac{1}{8}''$, $\frac{3}{16}''$, $\frac{1}{4}''$, increasing by eights to 1 inch.

The weight of slate is about 174 pounds per cubic foot, or, per square foot of various thicknesses, as follows:

Thickness, inches	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Weight, pounds.	1.81	2.71	3.62	5.43	7.25	9.06	10.88	12.69	14.50

Galvanized Iron.

Galvanized iron, both flat and corrugated, is used for the roofs and sides of buildings.

Flat iron is usually laid upon a sheathing of boards, but the strength of corrugated iron obviates the necessity for this. It is usually laid directly upon the purlins, and held in place by means of clips of hoop-iron, which encircle the purlin, and are spaced about 12 inches apart.

The corrugated sheets are fastened together with rivets of galvanized wire about ⅛ inch in diameter; the rivet-holes are spaced about 3 inches apart and are punched by machinery, so as to insure coincidence in the several sheets. The rivets must be well driven, so as to exclude rain, and the projecting edges at the eaves and gable-ends of the roof must be well secured, or the wind will loosen the sheets and fold them up.

TABLE 63.

GALVANIZED IRON.

WEIGHT PER SQUARE FOOT.

No. by Birmingham Wire Gauge.	Thickness in Inches.	Flat. Lbs.	Corrugated. Lbs.	No. by Birmingham Wire Gauge.	Thickness in Inches.	Flat. Lbs.	Corrugated. Lbs.
30	.012	.806	.896	21	.032	1.63	1.81
29	.013	.857	.952	20	.035	1.75	1.94
28	.014	.897	.997	19	.042	2.03	2.26
27	.016	.978	1.09	18	.049	2.32	2.58
26	.018	1.06	1.18	17	.058	2.68	2.98
25	.020	1.14	1.27	16	.065	2.96	3.29
24	.022	1.22	1.36	15	.072	3.25	3.61
23	.025	1.34	1.49	14	.083	3.69	4.10
22	.028	1.46	1.62	13	.095	4.18	4.64

Copper Roofing.

The copper used for roofing usually weighs from 12 to 14 ounces per square foot. It is laid on boards in the same manner as tin except that solder is not used. The thin sheets are often found with slight cracks or flaws, which if used in roofing will soon cause it to become leaky.

The weight of copper sheets used for flashing is from 12 to 18 ounces per square foot.

TABLE 64.

APPROXIMATE WEIGHT OF VARIOUS ROOF-COVERINGS.

Material.	Weight in Pounds per Square of Roof.
Yellow pine, Northern, sheathing, 1″ thick	300
Yellow pine, Southern, " " "	400
Spruce, " " "	200
Chestnut or maple, " " "	400
Ash or oak, " " "	500
Shingles, pine	200
Slates $\frac{1}{4}$″ thick	900
Sheet iron $\frac{1}{16}$″ thick	300
" " " " and laths	500
Iron, corrugated	100 to 375
" galvanized, flat	100 " 350
Tin	70 " 125
Felt and asphalt	100
Felt and gravel	800 " 1000
Skylights, glass $\frac{3}{16}$″ to $\frac{1}{2}$″ thick	250 " 700
Sheet lead	500 " 800
Copper	80 " 125
Zinc	100 " 200
Tiles, flat	1500 " 2000
" " with mortar	2000 " 3000
" pan	1000

Flashing.

Flashing is the name given to the covering of the joint at the junction of a sloping roof and a wall or chimney. The material employed is tin, copper, zinc, and lead. The flashing is formed by bending the edge of the sheet of metal at right angles for one, two, or more inches, and inserting the portion so bent into the joints of the masonry, and is stepped down as the roof descends.

Counter- or *cap*-flashings are of tin, copper, or lead, and are laid between the courses in the masonry, and turned down over the ordinary flashing. In flashing against stonework small grooves or reglets often have to be cut to receive the ends of the counter-flashing.

Flashing must be carefully executed to insure a tight roof.

Gutters are metal troughs or wood troughs lined with metal, for the purpose of carrying off rain-water from roofs. They are of different forms, and should have a fall of 1 inch in 10 feet to the leader or pipe which conducts the water to the ground or drain. The metal used is either tin, galvanized iron, zinc, or lead. The sides of gutters which abut against walls should be turned up from 6 to 8 inches against them and be covered with an apron. In gutters formed along the eaves of roofs the metal should be turned up and extend upon the top of the roof-boarding for not less than 10 inches and be securely nailed thereto.

Valleys are formed by the intersection of two roof-slopes forming a re-entering angle. They are made water-tight by covering with a flashing of tin, lead, or zinc, the sides of which are turned up along the roof-boarding for a distance of from 5 to 7 inches.

A "close valley" is one in which the roof-covering is mitred and flashed in each course so that no metal can be seen.

An "open valley" is one in which the metal is exposed to view in the finished roof.

Suitable provision must be made for the expansion and contraction of the metal used in valleys; when lead is used no sheet should be laid in a length greater than 10 feet without an expansion-joint formed by a "drip," "roll," or break of some kind.

The joints of the metal sheets in ridges, hips, and valleys should have a lap of about 4 inches.

The weight of lead used for flashings is usually 5 lbs. per square foot, for hips, ridges, and small gutters 6 lbs., and for flats and main gutters 7 lbs.

The weight of copper used for cap-flashing is usually sixteen ounces.

VII. Plumbing.

Inspection of Plumbing.

The work of the plumber comprises the placing of the pipes and fittings required for the water-supply and the removal of sewage from buildings. Each municipality usually has regulations giving specific directions as to the manner in which the work must be executed.

The duty of the inspector is:

1. To examine the quality and dimensions of the materials to be used.

2. To see that the work is executed in accordance with the specifications and in conformity with the plumbing regulations.

3. To test the finished work and see that it is gas- and water-tight.

Lead Pipes should be examined as delivered. The weight per foot, or the letter denoting the same thing, is stamped on the ends of the coils; after the ends are cut off it is difficult to ascertain whether they comply with the requirements of the specification, for the saw used in cutting spreads out the lead, thus giving the end an apparently greater thickness. Pipes showing unequal thickness of metal and those having a honey-combed appearance or in any way corroded should be rejected.

Table 65.

Weight of Lead Waste-Pipe.

$1\frac{1}{2}$ in.	2 lbs. per foot
2 "	3 and 4 lbs. per foot
3 "	$3\frac{1}{2}$ and 5 lbs. per foot
$3\frac{1}{2}$ "	4 lbs. per foot.
4 "	5, 6, and 8 lbs. per foot
$4\frac{1}{2}$ "	6 and 8 lbs. per foot
5 "	8, 10, and 12 lbs. per foot

Table 66.

WEIGHT AND THICKNESS OF LEAD PIPE.

Caliber.	Mark.	Weight per foot.	Thickness.	Mean bursting pressure.	Safe working pressure.	Caliber.	Mark.	Weight per foot.	Thickness.	Mean bursting pressure.	Safe working pressure.
ins.		lb. oz.	ins.	lbs.	lbs.	ins.		lb. oz.	ins.	lbs.	lbs.
$\frac{3}{8}$	AAA	1 12	0.18	1968	492	1	A	4 0	0.21	857	214
$\frac{3}{8}$	AA	1 5	0.15	1627	406	1	B	3 4	0.17	745	186
$\frac{3}{8}$	A	1 2	0.13	1381	347	1	C	2 8	0.14	562	140
$\frac{3}{8}$	B	1 0	0.125	1342	335	1	D	2 4	0.125	518	129
$\frac{3}{8}$	C	0 14	0.11	1187	296	1	E	2 0	0.10	475	118
$\frac{3}{8}$	-	0 10	0.087	1085	271	1	-	1 8	0.09	325	81
$\frac{7}{16}$	-	0 9½	0.08	775	193	1¼	AAA	6 12	0.275	962	240
$\frac{1}{2}$	AAA	3 0	0.25	1787	446	1¼	AA	5 12	0.25	823	205
$\frac{1}{2}$	-	2 8	0.225	1655	413	1¼	A	4 11	0.21	685	171
$\frac{1}{2}$	AA	2 0	0.18	1393	348	1¼	B	3 11	0.17	546	136
$\frac{1}{2}$	A	1 10	0.16	1285	321	1¼	C	3 0	0.135	420	105
$\frac{1}{2}$	B	1 3	0.125	980	245	1¼	D	2 8	0.125	350	87
$\frac{1}{2}$	C	1 0	0.10	782	195	1¼	-	2 0	0.095	322	80
$\frac{1}{2}$	D	0 9	0.065	468	117	1½	AAA	8 0	0.29	742	185
$\frac{1}{2}$	-	0 10	0.07	556	139	1½	AA	7 0	0.25	700	175
$\frac{1}{2}$	-	0 12	0.09	625	156	1½	A	6 4	0.22	628	157
$\frac{5}{8}$	AAA	3 8	0.23	1548	387	1½	B	5 0	0.18	506	126
$\frac{5}{8}$	AA	2 12	0.21	1380	345	1½	C	4 4	0.15	430	107
$\frac{5}{8}$	A	2 8	0.18	1152	288	1½	D	3 8	0.14	315	78
$\frac{5}{8}$	B	2 0	0.16	987	246	1½	-	3 0	0.12	245	61
$\frac{5}{8}$	C	1 7	0.117	795	198	1¾	B	5 0	-	-	116
$\frac{5}{8}$	D	1 4	0.10	708	177	1¾	C	4 0	-	-	93
$\frac{3}{4}$	AAA	4 14	0.29	1462	365	1¾	D	3 10	0.125	318	79
$\frac{3}{4}$	AA	3 8	0.225	1225	306	2	AAA	10 11	0.30	611	152
$\frac{3}{4}$	A	3 0	0.19	1072	268	2	AA	8 14	0.25	511	127
$\frac{3}{4}$	B	2 3	0.15	865	216	2	A	7 0	0.21	405	101
$\frac{3}{4}$	C	1 12	0.125	782	195	2	B	6 0	0.19	360	90
$\frac{3}{4}$	D	1 3	0.09	505	126	2	C	5 0	0.16	260	65
1	AAA	6 0	0.30	1230	307	2	D	4 0	0.09	200	50
1	AA	4 8	0.23	910	227						

Table 67.

THICKNESS AND WEIGHT OF WROUGHT-IRON PIPE—PLAIN AND GALVANIZED.

	Diameter.			Thickness.	Circumference.		Transverse Areas.			Length of pipe per sq. ft. of		Length of pipe containing one cubic foot.	Nominal Weight per foot.	Number of threads per inch of screw.
	Nominal internal.	Actual External.	Actual internal.		External.	Internal.	External.	Internal.	Metal.	External surface.	Internal surface.			
	inches.	inches.	inches.	inches.	inches.	inches.	sq. in.	sq. in.	sq. in.	feet.	feet.	feet.	pounds.	
Butt-welded.	1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
	1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
	3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
	1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
	3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
	1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
	1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
Lap-welded.	1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
	2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
	2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
	3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
	3½	4.0	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
	4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
	4½	5.0	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.34	8
	5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
	6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
	7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
	8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
	9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
	10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
	11	11.75	11.000	.375	36.91	34.55	108.4	95.03	13.37	.325	3.47	1.51	45.0	8
	12	12.75	12.000	.375	40.05	37.69	127.6	113.0	14.6	.299	3.18	1.27	49.0	8

TABLE 68.

WEIGHT OF BLOCK-TIN PIPE.

$\frac{3}{8}$ in.	$4\frac{1}{2}$, $6\frac{1}{2}$, and 8 ozs.	per	foot	
$\frac{1}{2}$ "	6, $7\frac{1}{2}$, and 10	"	"	"
$\frac{5}{8}$ "	8 and 10	"	"	"
$\frac{3}{4}$ "	10 and 12	"	"	"
1 "	15 and 18	"	"	"
$1\frac{1}{4}$ "	$1\frac{1}{4}$ and $1\frac{1}{2}$ lbs.		"	"
$1\frac{1}{2}$ "	2 and $2\frac{1}{2}$	"	"	"
2 "	$2\frac{1}{2}$ and 3	"	"	"

CAST-IRON SOIL-PIPES should be carefully examined for light weight and unequal thickness of metal; the poorer qualities are generally much thinner on one side than the other. The making of the joints must be closely watched to see that an excess of oakum is not used, nor that such improper materials as cotton waste, paper, and shavings are used in place of the oakum; also to see that a sufficiency of lead is used and that the joint is properly calked. Melted lead simply poured in will not make a tight joint, since on cooling the shrinkage draws it away from the iron, and it must be forced again into contact with the calking-iron, applied at every point of the circumference; the finished joint should show the marks of the tool all around.

The practice of partly filling the hub with lead and afterwards filling it up with putty should not be permitted. Such joints may stand the test, but are not durable.

TABLE 69.

WEIGHT OF CAST-IRON SOIL-PIPE.

(Extra heavy.)

Diameter. Inches.	Average Weight per Foot. Pounds.
2	$5\frac{1}{2}$
3	$9\frac{1}{2}$
4	13
5	17
6	20
7	27
8	$33\frac{1}{2}$
10	45
12	54

All sizes made in 5-ft lengths except 12-in., which is 6 ft. The length does not include the hub.

Testing Plumbing.

Several methods are practised for testing the tightness of plumbing, namely, air-pressure, water-pressure, peppermint, and smoke tests. The work is usually subjected to two tests The first is called the "Roughing Test," and the second the "Final Test."

The Water Test is the most satisfactory for the roughing test. It should be applied after the rough iron- and lead-work is in place, and just before setting the fixtures. The manner of applying it is as follows:

The main pipe is plugged outside of the house-trap and the system of pipes filled until the water rises to the top of the highest pipe. While the pipes are full of water all joints should be examined closely for leaks, and those showing signs of leaking at once calked. The pipes should also be closely examined for cracks, etc., and if any are found defective they should be marked for removal.

Peppermint Test.—The oil of peppermint, on account of its powerful odor, is extensively employed for testing the tightness of plumbing. It is sold expressly for this purpose in hermetically sealed vials containing two ounces. The method of using it is as follows: All the traps of the system are filled with water, the air- and ventilating-pipes are stopped up, the oil is poured into the main soil-pipe at its highest point. Usually this point is three or four feet above the roof. After the oil there is poured in a quart or more of boiling water, and the mouth of the pipe immediately stopped up. The peppermint is volatilized by the heat of the water, and the vapor, unable to escape, penetrates every part of the system. The pipes are then thoroughly examined The slightest odor of peppermint in the building indicates a defect either in a joint or in the pipe, which must be sought for and remedied.

The man who carries and applies the peppermint should not be permitted to enter the house until the test is completed, as he is liable to carry with him some trace of the odor, which will make the test useless. If no leak has been detected the plumbing can be pronounced safe.

THE SMOKE TEST is considered the best for the final test. It is applied by burning cotton waste or paper saturated with turpentine or kerosene in a suitable apparatus placed at the mouth of the main outlet-pipe. Each joint should be closely inspected, and the slightest odor of the smoke is an indication that the joint is not tight.

When air-pressure is used a pressure of 10 pounds per square inch is generally exacted.

During the final test the places where leaks are most liable to be found are at the back vent horns of porcelain fixtures, floor connections of water closets and coupling joints; these should be carefully examined, as in his hurry to finish the job the plumber may have forgotten to put in the washers.

The tightness of the water-service pipes is tested by a hydraulic test-pump under a pressure of about twice the pressure in the city supply-mains.

VIII. PLASTERING.

Definition of Plastering.

PLASTER is the name given to the various compositions employed for covering the interior walls and ceilings of buildings.

The term *stucco* is applied to the mortar coverings placed on the exterior of walls to protect the materials of the walls from disintegration, also to secure a smooth finish for the purpose of imitating stone.

The material most extensively employed for interior work is lime mixed with sand, with or without the addition of hair or plaster of Paris. Many patented cements and plasters are now on the market. They are known by specific names, such as *Keene's* cement, *Acme* and *Climax* cement plaster, *Windsor* cement, *Rockwall* plaster, *Adamant*, etc. The three last named are mixed with the proper proportion of sand by the manufacturers, and only require to be "wet up" before using. They should be manipulated strictly in accordance with the directions furnished by the manufacturers.

For exterior work Portland or Rosendale cement and sand are generally used.

The operation of plastering comprises: 1st. The preparing of the groundwork, which is formed of either *wooden laths*, *wire netting*, *perforated steel sheets*, *hollow brick*, or the *bare brick* or *stone walls*. 2d. The spreading and finishing of the plaster.

Plastering is divided into three classes, according to the manner in which it is executed, as *one-coat*, *two-coat*, and *three-coat* work.

The cements or mortars employed for plastering are usually divided into three classes, known as *coarse stuff*, *fine stuff*, and *finishing*.

Materials and Terms used in Plastering.

ANGLE-BEAD: Vertical beads, generally of wood, fixed to the exterior angles of walls, flush with the intended surface of the plaster.

ANGLE STAFF.—A strip of wood fixed to the vertical angle of a wall, flush with the plastering of the two planes. It is designed as a substitute for plastering in a situation so much exposed. A *round* staff is known as an angle-bead.

BLACK MORTAR is made by mixing anthracite (hard coal) coal dust with the lime, instead of sand.

BROWN COAT or Browning is the name given to the second coat in three-coat work. It is composed of the same ingredients as the first or scratch coat, with the addition of more sand to make it poorer, and therefore less liable to crack. Its thickness varies from one quarter to three eighths of an inch. If the first coat has become too dry it must be moistened with water before applying the browning.

On brick and stone walls the scratching is sometimes omitted, and the brown coat is applied directly to the surface of the wall, and of the proper thickness to receive the finishing coat.

COARSE STUFF.—The material employed for the first coat. When lime is used as the cementing medium it consists of about one part of quicklime to four parts of sand and about two pounds of hair. The sand and lime are mixed in the same manner as mortar for brickwork. The hair is added by the use of a rake or hoe. When the patent plasters are used the coarse stuff is usually furnished ready prepared by the manufacturers, and only requires to be mixed with water for use.

COAT.—A layer of plastering.

A *scratch-coat* is the first of three coats.

One-coat work is plastering in one coat without finish.

Two-coat work is plastering in two coats.

Screed-coat: A coat set even with the edges of the screeds.

Floated coat: A first coat laid on with a float.

Slippped coat is the smoothing off of a brown coat with a small quantity of lime putty.

The term "slipped" is also applied to the operation of applying the brown coat to the first coat without scratching; this operation is also called *laid-off work.*

CORNICE: Any moulded projection which crowns or finishes the part to which it is affixed.

DOTS: Nails driven into a wall to a certain depth, so that their protruding heads form a gauge of depth in laying on a coat of plaster.

DUBBING OUT: Filling up with coarse stuff irregularities in the face of a wall previous to finishing it with finer plaster.

FINE STUFF is made of pure lump lime slaked to paste with a moderate quantity of water and afterwards diluted with water to the consistency of cream, then placed in barrels, where it is allowed to settle and stiffen by evaporation to the proper condition for working.

Fine stuff is used for what is termed a "slipped coat," and with the addition of a small quantity of white sand or plaster of Paris it is used for a finishing coat.

FINISHING COAT.—The third or last coat of plaster.

FIRST COAT.—The primary coat of coarse stuff. That of two-coat work is called *laying* when executed on lath, and *rendering* when on brickwork. The first coat of three-coat work when on lath is called the *scratch*-coat, and when on brickwork *roughing in.*

FLOATED LATH AND PLASTER: Plastering of three coats, whereof the first is the *scratch-coat,* the second *floating* or floated work, and the last of fine stuff.

FLOATED WORK: Plastering rendered perfectly plane by means of a float.

FLOATING-SCREEDS: Strips of plaster previously set out on the work, at convenient intervals, for the *range* of the floating-rule or *float.*

FURRINGS are strips of wood nailed to joists, rafters, or walls to bring their surface to a level before nailing the plaster-laths.

GAUGE-STUFF OR HARD FINISH is composed of fine stuff and plaster of Paris, in proportions regulated by the degree of rapidity required in hardening. As it sets rapidly, it should be prepared in small quantities at a time. It is used for the finishing coat of walls, for cornices, mouldings, and other kinds of ornamentation. The usual proportions are, for finishing, 3 to 4 volumes of putty to 1 volume of plaster of Paris, and for cornices, etc., about equal volumes of each.

Hard finish is applied with the trowel, to the depth of about $\frac{1}{8}$ of an inch. It is polished with the water-brush and trowel. Hard finish is also made with 1 part of fine stuff, 2 parts of

white sand, and 1 part of marble-dust. When so composed it is called "stucco."

GROUNDS.—These are strips of wood sawed or planed carefully to a uniform thickness, three quarters of an inch or more where the plastering is to be three coat, or five eighths for two-coat work, secured to the furrings in such a way as to give convenient nailings for the subsequent finishings, one row, for instance, being set an inch or so below the top of the future base-board, two or three in the height of a wainscoting, a border around each door and window, and so on. Being of equal thickness, and straightened with the straight-edge and plumb-rule to correct any irregularity in the furrings or studs, they afford guides for bringing the plaster to an even surface.

HAIR.—The hair used for plastering is obtained from the hides of cattle. It should be long, free from grease, dirt, and salt (hair from salted hides will make the walls damp); it should be well beaten, so as to straighten out the hairs, and then dried. The mixing of the hair and the mortar must be carefully done, so as not to break the hair into short bits.

Hair is put up in paper bags, each bag being supposed to contain one bushel of hair when beaten up. It is sold by the bushel, which weighs from 14 to 15 pounds. It is classed according to quality as Nos. 1, 2, and 3, the last being the best.

Jute is being used as a substitute for hair, and with satisfactory results.

HAND-FLOATING.—This is performed by using the float in the right hand, and a hair-brush holding water in the left; both instruments are passed quickly over the wall at the same time, the brush preceding the float and wetting the surface to the required degree. The firmness and tenacity of plastering are very considerably increased by hand-floating. The operation must take place while the mortar is green, when it is intended as a preparation for the setting coat.

HARD FINISH: See Gauge-stuff.

KEENE'S CEMENT is a plaster produced by recalcining plaster of Paris after soaking it in a saturated solution of alum. It is made in two qualities, coarse and superfine. The latter is white and capable of receiving a high polish; the former is not so white or able to take so good a polish, but sets hard. It is used for interior decorations, artificial marbles, cornices, etc.

LAID AND SET: The terms used to describe two-coat plastering.

LATHS, WOOD.—Plastering-laths are usually of mill-sawed white or yellow pine, spruce, or hemlock, in lengths of 4 feet, and are about 1½ inches wide and ¼ inch thick, and should be free from knots.

They are nailed up horizontally to the studs and spaced ⅜ of an inch apart; if placed nearer together the mortar will not be effectually pressed through the spaces, and its hold will be feeble; if farther apart it will not, while soft, sustain its own weight. Joints should be broken every course; if the ends all joint on one stud the plaster will crack at that point when the stud dries and shrinks. In placing laths above door- and window-heads they should extend at least to the next stud beyond the jamb, so as to prevent the radiating cracks which are apt to appear at that point.

No deviation from the horizontal direction of the laths should be permitted, as cracks will show in the finished work where the change of direction was made.

Laths are sold by the 1000 in bunches containing 100 laths.

A hundred square feet of plastering requires about 1400 laths.

A lather will nail up from 10 to 20 bunches in a day.

LATHS, METALLIC.—Metallic lathing is now made in a variety of forms, to meet the requirements of the different plastering compositions and the varying conditions of construction.

In placing metallic lathings care is necessary to see that they are securely fastened and stretched, so that there may be no bulges or irregularities in the finished work.

LATH-NAILS are from ¾ to 1 inch long. To lath 100 square yards requires 10 pounds of 3d. nails.

LAYING: The first coat of plastering in two-coat work.

LIME: The lime used in plastering should be the best quality wood-burned stone lime.

LIME MORTAR.—The mortar for plaster should be well made. The lime should be thoroughly slaked, and brought to a paste or putty state. It should remain in the mortar-bed until it is perfectly cool. In this way only can the occurrence of particles of unslaked or partially slaked lime in the mortar be guarded against; the presence of such particles in the finished work causes cracks and blisters by absorbing moisture.

Authorities disagree as to the length of time the lime should be allowed to cool. The usual time is from six to fourteen days.

Newly made mortar, if immediately applied, will chip, crack, and become mottled.

In slaking the lime care must be taken that neither too much nor too little water is used. If too much is used the lime will be "chilled," and lose a part of its strength; if too little it will "burn," and a portion of it will pass into the mortar-bed unslaked and cause trouble there.

Mixing the Mortar.—In regard to the manner of mixing the practice varies. 1st. The lime is slaked and when thoroughly cooled sufficient for the day's work is taken from the heap and mixed with the required proportions of sand and hair, then immediately spread upon the wall. The disadvantages of this process are the difficulty of distributing the hair evenly through the stiffened paste without the help of water to loosen the tufts, and the increased labor required to work the mortar. The advantages are the perfect hydration of the lime, by which chip-cracks and blisters are avoided; the smoothness and hardness of the finished plastering, and its greater tenacity, since the hair not being added until the lime is cold retains its full strength instead of being burned and corroded by steeping in the hot caustic mixture, which is the first result of slaking. 2d. The lime is spread out, water poured on, and after a little stirring the hair is added and mixed with the steaming liquid. The sand is then added and mixed after which the mixture is piled for use. The hair in this method deteriorates as fast as the lime improves, and a season of cooling, which would be very beneficial to the latter ingredient, will nearly destroy the former, so that a course midway between the extremes should be taken.

LIME PUTTY is lime dissolved in a small quantity of water, fresh lime being added from time to time, and the mixture stirred with a stick until the lime is entirely slaked, and the whole becomes of the consistence of cream; it is next while still warm sifted or run through a hair sieve in order to separate the coarser parts of the lime, and is then ready for use. The material which remains in the sieve should be thrown away.

MARBLE-DUST is sometimes used for hard finishing. It should not be too fine, as it will then not make good work. If left about as coarse as sand it will be found to give the best satisfaction.

When marble-dust is used it should not be mixed with the lime until a few moments before using, and no more should be prepared at one time than can be used up at once, as it "sets" quickly, after which it should not be used.

The marble-dust must be prepared especially for plastering,

and must not be the refuse from either grinding or sawing marble for commercial purposes, as such refuse contains particles of iron which will oxidize and show rust-spots in the finished plaster.

ONE-COAT WORK: Plastering in one coat without finish.

PARGE-WORK; PARGETTING: A particular sort of plaster-work, having patterns and ornaments raised upon it or indented.

PUGGING: Stuff laid between ceilings or on partition-walls to deaden sounds.

PLASTER OF PARIS is a white powder of sulphate of lime produced by the gentle calcination of gypsum to a point short of the expulsion of the whole of the moisture. Paste made from it sets in a few minutes, and attains its full strength in an hour or two. At the time of setting it expands in volume, which makes it valuable for filling up holes and other defects in ordinary work. It is added to lime and other compositions in order to make them harden more rapidly. It is used for making all kinds of ornaments for ceilings, cornices, angle-beads, etc. Some of these are cast by forcing it when in a pasty condition into moulds made of wax, plaster, etc. There are three qualities of plaster of Paris on the market—the *superfine*, *fine*, and *coarse*.

It should be mixed by putting the powder into the water, not the water amongst the powder.

RENDERED AND SET is complete two-coat work on brick or stone.

RENDERING: The first coat of plastering on brickwork. It is followed by the *floating coat* and the *setting coat*.

ROUGH CAST: A mode of finishing outside work by dashing over the second coat of plaster while quite wet a layer of washed fine gravel or shells min g with lime and water.

RULE: A strip or screed of wood or plaster placed on the face of a wall as a guide to assist in keeping the plane surface.

SAND for plaster should be angular, not too coarse nor too fine, and should be free from all foreign substances, particularly fine loam or clay. Clean river, or pit-sand, carefully screened, is generally considered the best for plaster. Sea-sand is deficient in sharpness and contains alkaline salts, which attract moisture, and is therefore unfit for use in plaster. Sand containing clay or loam may be cleansed by washing in a wooden trough having a current of water flowing through it; when thoroughly cleaned it will leave no stain when rubbed between moist hands. Salts can

be detected by the taste, and the size and sharpness can be judged by the eye or by the use of a microscope.

SAND-FINISH has a rough surface resembling sandpaper ; it is composed of lime putty and coarse sand in equal proportions, and it is finished with a wooden or cork float.

SCAGLIOLA is composed of plaster of Paris with alum and some color mixed into a paste, and afterwards beaten on a prepared surface with fragments of marble. It is, when properly prepared, very hard and susceptible of a fine polish. It is used in the formation of columns, walls, and ornamental work in imitation of marble. The surface on which it is to be placed has a rough coating of lime mortar with hair.

When the composition has been laid on the prepared surface and is properly hardened the polishing is commenced by rubbing the surface with pumice-stone and dampening it with a wet sponge. It is next rubbed with tripoli and charcoal, and thereafter with a felt rubber dipped in oil and tripoli, and finally finished off with felt or cotton dipped in oil only.

SCRATCH-COAT.—The first coat applied. It is intended to form a foundation for the succeeding coats. Its thickness varies from one quarter to three quarters of an inch. When lime is used it is composed of one part of quicklime to four parts of sand and about two pounds of hair to each bushel of lime ; this mixture is generally called *coarse stuff*. The operation of applying it to bare brick or stone walls is termed *rendering*, and when applied on laths *laying*. When completed and partially dry, though still quite soft, it is roughly *scored* or *scratched* (hence its name) with pointed sticks nearly through its thickness by lines running diagonally across each other; these scorings are from two to four inches apart, and assist the adhesion of the succeeding coat.

Before applying the scratch-coat to solid brick or stone walls the joints of the masonry should be raked out to a depth of at least one half inch the surface freed from dust and moistened with water. Old masonry if smoked or greasy should be also roughened.

In applying to wood or metal laths the coarse stuff should be well tempered, and of such moderate consistency that when pressed with force against the laths it will penetrate between them and bend down on the inside so as to form a good key. As this is the only way in which the whole body of the plaster can be kept on the walls, it is very essential that this work be well executed. Sometimes when plaster is applied to the surface of

brick or stone walls the scratch-coat is omitted and the brown coat applied directly of the required thickness to receive the finishing coat.

SCREEDS are a kind of gauge or guide formed by applying to the first or scratch coat, when partly dried, vertical or horizontal strips of plastering-mortar, about eight inches wide and two to four feet apart, all around the room. These are made to project out from the first coat to the intended face of the second coat, and while soft are carefully made perfectly straight and out of wind with each other by means of the plumb-line, straight-edge, etc. When this is done the second coat is put on, filling up the horizontal spaces between them, and is readily brought to a perfectly flat surface corresponding to that of the screeds by means of long straight-edges extending over two or more of the screeds.

SCREED-COAT AND SET are terms used also to designate two-coat work. The screeds are strips of mortar, six to eight inches in width and of the required thickness of the second coat, applied on the scratch-coat at the angles of the room, and parallel, at intervals of 3 to 5 feet, all over the surface to be covered. These screeds are carefully worked so as to be accurately in the same plane by the frequent application of the straight-edge in all possible directions. When they have become sufficiently hard to resist the pressure of the straight-edge the "filling out" of the interspaces flush with the surface of the screeds takes place, so as to produce a continuous, straight, and even surface. The surface is then hand-floated.

SKIM-COAT is generally composed of lime putty and washed beach-sand in equal proportions. It is finished by trowelling over the surface from three to five times with a steel trowel and wet brush.

SLIPPED-COAT.—A slipped-coat is merely a smoothing off of a brown coat (coarse stuff) with the smallest quantity of *fine stuff* or lime putty that will answer to secure a comparatively even surface.

STEARATE OF LIME is composed of lime and beef suet. It is used as a finishing coat. The walls are prepared in the usual manner, with a scratch-coat and a browning coat, the latter being "floated." When the browning is sufficiently dry the "stearate" is applied "hot" with an ordinary whitewash-brush. Two coats are generally applied.

STUCCO for interior work is composed of lime, putty, and white

sand. The usual proportions are three to four volumes of sand to one of putty (marble dust is sometimes added). It is applied with the trowel to the thickness of about one-eighth of an inch. It is well hand-floated, the water-brush being used freely while so doing. After the wooden float has been used it is gone over with the cork float in the same manner. The surface is polished with the trowel and brush.

STUCCO (COMMON) consists of three parts clean sharp sand and one part of lime.

STUCCO (BASTARD) consists of fine stuff and a small quantity of sand, and sometimes hair is added.

STUCCO (TROWELLED) is composed of two-thirds fine stuff and one-third fine clean sand. It is used for surfaces intended to be painted.

STUCCO.—The name stucco is also given to the plastering on exterior walls. The materials used for this work are generally Portland or Rosendale cement and sand. The mortar made from either of these cements is applied in two coats, laid on in one operation. That for the first coat should be somewhat thinner than that for the second, in order that it may be pressed into thorough contact with the wall. The second coat is applied upon the first, while the latter is yet soft. The two coats thus laid should form one compact coat of about one-half inch in thickness. The finished stucco should be kept shaded from the direct rays of the sun for some days, and be moistened from time to time.

As a modification of the above process the first coat is sometimes omitted, or rather replaced by a wash of thick cream of pure cement, applied with a stiff brush from time to time, just before the mortar is put on. If the brushwork is faithfully done, and not allowed to dry before the surface receives the stucco, an intimate contact and firm adhesion are sure to result.

A necessary precaution in this kind of work is to secure the services of a faithful workman—one who will not spare his strength, or lay on any of the mortar too loosely, or on too dry a surface; otherwise there will be portions without adhesion that will be thrown off on the first occurrence of frost.

After the stucco has been on for a few days the whole surface should be carefully sounded with a small iron instrument like a tack-hammer when all places destitute of adhesion will be readily detected by their hollow sound. From these the stucco should

be carefully removed, the surface roughened and wetted, and new mortar applied.

TWO-COAT WORK.—Plastering in two coats is done either in a *laying coat* and *set*, or in a *screed-coat* and *set*. The *screed*-coat is also called the *floated* coat. *Laying* the first coat in two-coat work is resorted to in common work instead of *screeding*, when the finished surface is not required to be exactly even to a straight edge.

After the first coat, whether it be a laying coat or a screed-coat, has become partially dry so as to resist the pressure of the trowel, it is ready for the *setting* or finishing coat. This may be either in *slipped work*, stucco, *bastard stucco*, or *hard finish*. In all cases the surface to receive it must be roughened or scratched with a suitable tool, and if too dry must be moistened.

THREE-COAT WORK.—The first and second coat are termed respectively the *scratch*-coat and *brown* coat, and the third coat is either *hard-finish* or *stucco*.

WHITE-COATING generally means a composition of lime, putty, plaster of Paris, and marble dust or white sand.

Tools Used in Plastering.

DARBY: A float-tool; it is either single or double, as may be required, the single being for one man to use, the double for two. The single one should be 4 feet 5 inches long and about 4 inches wide, with a handle near one end, and a cleat near the other end running lengthwise of the blade. The long darbys have a handle on each end.

FLOAT: A trowel used in spreading or *floating* the plaster on to a wall or other surface.

The *Long Float* is of such a length as to require two men to use it.

The *Hand Float*, made of pine, is used for finishing.

The *Quick Float* is used in finishing mouldings.

The *Angle Float* is shaped to fit the angle formed by the walls.

The *Cork Float* is used for the same purpose as the wooden float.

HAWK: A square piece of board with a handle in the centre of one side; it is used for holding and conveying the mortar.

HOD for carrying mortar is formed by two boards, eleven and twelve inches wide respectively, and eighteen inches long, the wide board being nailed on the edge of the narrow one, making a right-

angled trough: one end is inclosed, and the end piece is rounded over the top; the boards forming the sides are rounded at the opening A handle about four feet long and two inches in diameter is fastened about two inches forward of the middle, nearer to the open end, and a piece of wood called a pad is fitted with a V groove on the angle just back of the handle.

MITRING ROD is a tool one foot or more long, and about one-eighth of an inch thick and three inches wide; the longest edge is sharp, and one end is bevelled off to about thirty degrees. It is used for cleaning out quirks in mouldings, angles, and cornices.

MORTAR BEDS are made of rough plank, and should be strongly put together.

MORTAR-BOARD is a board similar to a table top, and is about forty inches square. It is used for holding the mortar delivered from the *hod*.

MORTAR-BOX: See Slack-box.

MOULDS: These are used for running cornices, and are infinite in shape and variety The reverse of the contour of the cornice is cut out of sheet copper or iron, and is firmly attached to a piece of wood which is also cut out the reverse shape of the intended moulding.

PADDLE: This is a piece of pine wood less than three inches wide, and six long, by one thick: it is made wedge-shaped on one end, the other end being rounded off for a handle. Its use is to carry stuff into angles when finishing.

POINTER.—This is a trowel of nearly the same shape as a bricklayer's, but only about four inches long. It is used for mending broken or defective cornices, etc.

SCRATCHER.—This is generally made of short pieces of pine two inches wide and one inch thick; five or seven of them are nailed to two cleats, and are placed about an inch apart. The centre one is left longer than the others, so as to form a handle. The ends opposite to the handle are cut off square and pointed. When completed it resembles a gridiron. Its use is to make grooves in the first coat to form a key for the second coat.

SIEVES of either hair or wire are used for straining through putty for finishing.

SLACK-BOX.—This is generally made of boards, eight or nine feet long and from two to four feet wide, and twelve or sixteen inches in depth. The bottom should be made as tight as rough boards will permit.

STOPPING AND PICKING-OUT TOOLS, also called *mitring tools*, are made of fine steel plates, seven or eight inches long, and of various widths and shapes. They are used for modelling and for finishing mitres and returns to cornices by hand where the moulds cannot work.

TROWELS are of several kinds: the one for ordinary use is formed of light steel four inches wide and about twelve inches long; this is the laying and smoothing tool. The *gauging trowel* is used for gauging fine stuff for courses, etc.; it varies in size from three to seven inches in length, and in form resembles a bricklayer's trowel.

TABLE 70.

QUANTITY OF MATERIALS REQUIRED FOR PLASTERING.

Materials.	One-coat Work. Scratch-coat. ⅝″ Thick.	Two-coat Work. ⅝″ Thick.	Three-coat Work. ¾″ Thick.	Hard Finish. ⅛″ Thick.
	Per Sq. Yd.	Per Sq. Yd.	Per Sq. Yd.	Per Sq. Yd
Lime (unslaked)	.15 cu. ft.	.25 cu. ft.	.33 cu. ft.	.10 cu. ft.
Sand	.23 " "	.38 " "	.38 " "	....
Hair	.10 lb.	.17 lb.	.18 lb.	....
Water	1½ gals.	2 gals.	2½ gals.	1 gal.
Plaster of Paris	....	....	....	.03 cu. ft.

TABLE 71.

AREA COVERED WITH ONE CUBIC FOOT OF CEMENT AND SAND

Materials. Cubic Feet.	Thickness. Inches. ½	¾	1
	Sq. Yds.	Sq. Yds.	Sq. Yds.
Cement 1	2¼	1½	1⅛
" 1, sand 1	3⅛	2½	1¾
" 1, " 2	4⅝	3⅜	2⅛

For rubble or very rough brick walls the area in the above table will be decreased.

Inspection of Plastering.

MORTAR.—It is not always easy to tell by the appearance of a heap of plastering-mortar whether the lime, sand, and hair are of good quality and in suitable proportions. If properly mixed, which will be shown by the absence of streaks in the mass, a small quantity should be taken up on a trowel. If it hangs down from the edge without dropping off the quantity of hair is sufficient.

On drying a small quantity of the mortar an excess of sand will be shown by its being easily rubbed away with the fingers.

The quality of the lime is best tested by observing the slaking. It should slake energetically and fall into a smooth paste without any refractory lumps or particles of "core." If such are found all the packages of that brand should be rejected.

During the application of the scratch-coat on laths the operation should be closely watched to see that the workman exerts sufficient pressure to force the mortar through the openings and cause it to bend over and form a hook or key. It is necessary that ceiling-plaster should clinch well over every lath and wall-plaster over every second or third. The scratching should be thoroughly executed. It affords the key for the second coat. The application of the second or brown coat should not be begun until the first coat is thoroughly dry.

After the brown coat is dry the rule-joints at the angles should be first made, then screeds worked in between. The straightness and accuracy of corners and angles should be insisted upon, as the eye detects any irregularity in the angle between walls, or between the wall and ceiling, while inequalities of the intermediate portions are not so noticeable. When the screeds have hardened a little the space between them is filled in with "brown" mortar, which is easily made perfectly even by means of the straight-edge.

Cornices should be run before the last coat of plaster is applied. The angles should be as rough as possible, to give them sufficient "key." If there is a large mass of mortar to be left in the angle nails should be driven to hold up the coarse mortar used for "dubbing out" the cornice before the finishing coat is applied.

See that the laths are properly spaced and nailed and that the joints are properly broken. When wire lathing is used see that

it is securely fastened and well stretched, so that there may be no bulges or irregularities in the finished work.

In applying plaster directly to the surface of brick or stone walls the joints should be raked out to a depth of at least half an inch, the surface cleaned of dust and then thoroughly wetted.

Care is necessary to prevent the injury of plastering by freezing in winter or by too rapid drying in summer. From the latter cause the finished work near the windows is often found covered with a network of minute cracks, particularly on the side which the wind strikes, while a breeze barely at the freezing-point will cover the surface with radiating crystals, disintegrating it so that on thawing again the mortar will scale off in patches. The remedy for this is to keep all openings protected by temporary windows or screens, consisting of wooden frames covered with cotton cloth well fitted to the openings. These coverings should not be removed until the glazed sashes are ready to take their place, because by opening the windows while the plaster is green and admitting a draft those portions exposed to its action will dry so rapidly that it will crack, warp, and break bond.

PLASTERING TILE ARCHES.—When it is intended to plaster the under side of tile arches the inspector should see that the smoke and soot from the boiler used for the hoisting-plant are not allowed to strike the arches, as neither can be removed, and they will stain the plaster. For the same reason he should see that only clean water is used for mixing the mortar, and that it is not allowed to flow over the arches.

Plaster should not be applied to the arches until they are well dried out, otherwise stains are liable to appear which cannot be concealed even by oil-paint.

IX. GLASS AND GLAZING.

Glass.

The defects of glass are very apparent, and consist of waves, air-bubbles, twists, sand-specks, blisters, and patches of color. The difference between first and second quality glass is very slight, and must be learned by observation. Double-thick glass shows unevenness of surface more plainly than single-thick.

The tensile strength of common glass varies from 2000 pounds to 3000 pounds per square inch, and its crushing strength from 6000 pounds to 10,000 pounds.

Ordinary window-glass is sold by the box, whatever may be the size of the panes; a box contains as nearly 50 square feet as the dimensions of the panes will allow. Panes of any size can be made to order. A great variety of sizes are usually kept in stock, ranging from 6 × 8 to 44 × 56 inches.

SHEET GLASS is of various qualities, weighing from 12 to 42 ounces per square foot.

SINGLE THICK GLASS is about $\frac{1}{16}$th of an inch thick.

DOUBLE-THICK is about $\frac{1}{8}$th inch thick.

PLATE GLASS ranges in thickness from $\frac{1}{16}$th to $\frac{1}{8}$th of an inch.

POLISHED PLATE ranges from $\frac{3}{16}$ to $\frac{1}{4}$ inch thick.

ROUGH-CAST PLATE, used for flooring, is usually 6 inches wide, 11 inches long, and from $\frac{1}{4}$ to 1 inch thick.

CROWN GLASS is made in single and extra thick. It is said to be more free from color than sheet glass, and it has a finer surface.

FRENCH POLISHED PLATE GLASS is considered to be the highest grade of window-glass in the market. May be obtained in lights varying from a piece one inch square to a light 8 feet wide and 14 feet long.

The weight averages $3\frac{1}{4}$ pounds per square foot.

TABLE 72.

THICKNESS AND WEIGHT OF SHEET GLASS.

No.	Thickness. Inches.	Weight per. Sq. Ft. Ounces.	No.	Thickness. Inches.	Weight per Sq. Ft. Ounces.
12	.059	12	21	.100	21
13	.063	13	24	.111	24
15	.071	15	26	.125	26
16	.077	16	32	.154	32
17	.083	17	36	.167	36
19	.091	19	42	.200	42

TABLE 73.

THICKNESS AND WEIGHT OF SKYLIGHT-GLASS.

Dimensions. Inches.	Thickness. Inches.	Weight per Sq. Lbs.
12 × 48	$\frac{5}{16}$	250
15 × 60	$\frac{1}{4}$	350
20 × 10	$\frac{3}{8}$	500
94 × 156	$\frac{1}{2}$	700

Glazing.

Glass is secured in the sashes by triangular pieces of tin called *sprigs* and putty ; the panes of glass should be a little smaller than the sash in which they are to rest, so that the edges of the glass nowhere actually touch the frame.

A layer of putty is spread over the narrow part of the rebates, upon which the glass is firmly bedded—this is called the *back-putty ;* as the glass is pressed upon it the superfluous putty is squeezed out round the edges of the panes and cut off.

The glass is then *front-puttied,* the rebate is *stopped,* that is, filled in with putty to a triangular section.

Care must be taken that the putty does not project beyond the front of the rebate so as to be seen from the inside of the window.

Glazing in roofs is usually done without putty ; galvanized-iron sashes are usually employed for this purpose.

Large panes of plate glass are not usually back-puttied, rubber and leather are usually employed for heavy panes.

and hearth-slags, are next charged into a special furnace with a very hot coke fire. The products of this smelting are pig lead, slags poor enough in lead to be thrown away, and the "fume," which in this case is perfectly white and in a fine state of subdivision, suitable for a white pigment, and is sold as such either dry or ground in oil. It is known to the trade as Joplin lead, from the place where it was first manufactured, Joplin, Mo. It is also known as Picher lead, from the name of the manufacturing company.

ZINC WHITE (*oxide of zinc*) is produced either by distilling metallic zinc in retorts under a current of air, or by a process similar in principle to that described under Sublimed Lead. Zinc white dissolves in hydrochloric acid.

OXYSULPHIDE OF ZINC, prepared by precipitating chloride or sulphide of zinc by means of a soluble sulphate of sodium, barium, or calcium, is used as the base of some patented paints.

RED LEAD (*red oxide of lead or minium*) is produced by raising the oxide of lead (known commercially as *litharge* or *massicot*) obtained in the melting of argentiferous lead ores to a high temperature, short of fusion, during which it absorbs oxygen from the air and is converted into red lead. It is prepared in specially constructed furnaces, on the hearth of which the lead is melted and kept at a low red heat, and continually stirred to allow oxidation to occur. The massicot so formed during 24 hours of exposure to the heat is taken out, ground to a fine powder and washed, and again subjected in the same furnace for 48 hours to the same low red heat, until a sample taken out appears a dark red while hot and a bright red when cooling. The furnace is then closed and left to cool slowly, a condition most essential to the success of the operation.

There are other methods of preparing red lead, but the above is the most important.

The carbonate of lead is also used instead of the oxide for conversion into red lead, but when the temperature is properly regulated another pigment is obtained, called orange lead. Red lead thus produced retains a little carbonic acid and forms a pigment known as Paris red

ADULTERATION OF RED LEAD.—Commercial red lead contains all of the foreign metallic oxides—such as the oxides of silver, copper, and iron—with which the litharge used in preparing it is contaminated. It is also adulterated with the red oxide of iron, boles, or brick-dust. These substances remain un-

dissolved when the red lead is digested in warm dilute nitric acid; boiling hydrochloric acid extracts the sesquioxide of iron from the residue. When red lead thus adulterated is ignited there remains a mixture of yellow lead oxide and the red substances that have been added to it. Brick-dust may be detected by heating the lead in a crucible and treating it with dilute nitric acid. The lead will be dissolved, but the brick-dust will remain.

ANTIMONY VERMILLION (*sulphide of antimony*), produced from antimony ore, is used as a substitute for red lead.

OXIDE OF IRON is produced from the brown hematite ores. The ore is roasted, separated from impurities, and then ground. Tints varying from yellowish brown to black may be obtained by altering the temperature and other conditions under which it is roasted. It is also produced as a by-product in the manufacture of aniline dyes.

VEHICLES.

RAW LINSEED-OIL is produced by compressing flaxseed. The oil as first expressed from the seed is allowed to settle until it can be drawn off clear.

Raw linseed-oil, when of good quality, should be pale in color, perfectly transparent, almost free from odor, and sweet in taste. Darkness in color and slowness in drying indicate inferior quality. These defects are diminished and the quality of the oil improved by age.

The oil should not be used within six months after being produced; it improves by keeping.

Raw oil is more suited for delicate work than boiled oil, as it it is thinner, and lighter in color. When it is to be used for such purpose it is clarified by adding an acid (usually muriatic), which is afterwards carefully washed out.

Raw oil spread in a thin film on glass or other non-absorbent material will take from two to three days to dry, according to the state of the weather.

The drying quality and the color of raw oil may be improved by adding about one pound of white lead to every gallon of oil and allowing it to settle for about a week. The oil is drawn off, and the lead can be used for painting rough work.

BOILED LINSEED-OIL is prepared by heating raw oil either alone or with driers, such as red lead, litharge, etc., or by passing a current of air through raw oil.

Boiled oil is thicker and darker in color than raw oil.

Good boiled oil spread in a thin film upon glass should dry in from 12 to 24 hours, according to the state of the weather.

Raw oil is used for interior work and for grinding up colors. Boiled oil is used for exterior work and is not suited for grinding color.

ADULTERATION AND SUBSTITUTES.—Linseed-oil is subject to various adulterations, as by the addition of fish, hemp, cotton-seed, resin, and mineral oils. These adulterations are difficult to detect; they change the odor and specific gravity, and deteroriate the drying quality.

Raw oil treated with liquid japan drier is frequently sold as boiled oil. Such oil is said to be boiled through the "bung-hole."

As substitutes, fish-oil and cotton-seed oil treated with benzine are used; also oils prepared by patented processes, as Lucal-oil, Sipes-oil, Japan-oil, etc.

SOLVENTS.

SPIRITS OF TURPENTINE is a volatile oil obtained by the distillation of the turpentine obtained by tapping or boxing the yellow-pine trees of the Southern States. The residuum left after distillation is called *rosin* to distinguish it from the finer resins used for varnish, etc

Good turpentine is colorless, and has a pleasant pungent odor; adulterated or inferior qualities have a disagreeable odor.

Turpentine is used in paints to make them work more smoothly, and as a solvent for resins and other substances.

Good turpentine should have a very slight residue when evaporated. When spread upon any surface in a thin layer it should dry in 24 hours, leaving a hard dry varnish.

Turpentine is often adulterated with mineral oil. The pure turpentine loses bulk by evaporation, and gains weight upon exposure to the air. Adulterated with mineral oils, the spirit evaporates, leaving the oil without any assistance in hardening.

Benzine, naphtha, etc., are used as substitutes.

STAINERS OR PIGMENTS.

Blacks.—LAMPBLACK is the soot produced by burning oil, resin, bituminous coal, resinous woods, coal-tar, or tallow.

VEGETABLE BLACK is the name given to black obtained from burning oil.

IVORY-BLACK is obtained by calcining waste ivory in close vessels, and then grinding.

BONE-BLACK is prepared from bones in a similar manner to ivory-black.

Blues.—PRUSSIAN BLUE is made by mixing prussiate of potash with a salt of iron. The prussiate of potash is obtained by calcining and digesting old leather, blood, hoofs, or other animal matter with carbonate of potash and iron filings.

BLUE LEAD is obtained by subliming lead as described under Sublimed White Lead.

COBALT BLUE is an oxide of cobalt made by roasting cobalt ore.

BLUE OCHRE is a natural-colored clay. Other blues are made from mixtures of soda, silica, alum, sulphur, copper, lime, etc.

Browns generally owe their color to oxide of iron.

RAW UMBER is a clay colored by oxide of iron.

BURNT UMBER is raw umber burnt to give it a darker color.

BURNT SIENNA is produced by burning raw sienna.

SPANISH BROWN is a clay or ochre colored by iron.

Greens may be made by mixing blue and yellow pigments, as Prussian blue, chromate of lead, and sulphate of baryta ; but such mixtures are less durable than those produced direct from copper, arsenic, etc.

Greens known by various trade names are produced by treating the acetate or carbonate of copper with sal-ammoniac. Chalk, lead, and alum are sometimes added.

Greens are also made from the arsenites of copper, and from cobalt and ferrous oxide of zinc.

Reds.—RED LEAD. For description, see page 342.

VERMILLION is a sulphide of mercury, found in a natural state as *cinnabar*.

Vermillion is adulterated with red lead brightened with eosine, and with logwood mixed with molasses.

Vermillion is tested by heating in a test-tube. If genuine it should entirely volatilize.

Artificial vermillion is made from a mixture of sulphur and mercury.

German vermillion is the tersulphide of antimony, and is of an orange-red color.

INDIAN RED is ground hematite ore.

CHINESE RED AND PERSIAN RED are chromates of lead produced by boiling white lead with a solution of bichromate of potash.

VENETIAN RED is obtained by heating sulphate of iron pro-

duced as a waste product of tin and copper works. It is often adulterated by mixing sulphate of lime with it.

Yellows.—CHROME YELLOWS are chromates of lead produced by mixing dilute solutions of acetate or nitrate of lead and bichromate of potash.

NAPLES YELLOW is a salt of lead and antimony.

YELLOW OCHRE is a natural clay colored by oxide of iron.

Other yellows are made from arsenic or oxychloride of lead.

RAW SIENNA is a clay stained with oxides of iron and manganese.

PROPORTIONS OF INGREDIENTS.

The proportions of the materials used in preparing paints vary greatly. They depend upon the material to be painted, being different for wood and iron; the kind of surface, whether porous or not, the porous requiring more oil; and the degree of exposure to which the paint is to be subjected.

If the surface is subsequently to be varnished, the paint must contain a minimum of oil. If the work is exposed to the sun, turpentine is necessary to prevent blistering. The proportions also depend upon the quality of the materials used. More oil and turpentine will combine with pure than with impure white lead. And the different coats of paint vary in composition: the first coat on new work requires more oil. Turpentine is necessary to cause adherence to old work.

The quantity of paint required for a given surface may be approximately ascertained by the following rule:

Divide the square feet of surface to be painted by 200. The quotient is the number of gallons of liquid paint required for two coats.

Divide the square feet of surface to be painted by 18. The quotient is the number of pounds of white lead required for three coats.

Special Paints.

BITUMINOUS OR ASPHALT paints are prepared by dissolving bitumen in paraffine, petroleum, naphtha, and benzine.

P. B. PAINT is composed of asphaltum dissolved in bisulphide of carbon.

BLACK BRIDGE PAINT is composed of asphaltum, linseed-oil, turpentine, and kauri-gum.

COAL-TAR PAINT is composed of coal-tar either alone or mixed with lime or other inert pigment, and mixed with fish or mineral oils. Coal-tar paint is frequently substituted for asphaltum paint.

GRAPHITE PAINT is prepared by mixing graphite with boiled linseed-oil to which a small percentage of litharge, red lead, manganese, or other metallic salt has been added at the time of boiling.

PRINCE'S METALLIC PAINT is made from a blue magnetic iron ore, containing about 50 per cent of iron peroxide, 25 per cent limestone, and 25 per cent sulphur; it is mined in Carbon Co., Pa. The ore is broken into small pieces, roasted, and then ground. During this process it loses one third of its weight by the volatilization of the sulphur and other constituents. The prepared pigment is said to contain 72 per cent of iron peroxide and 28 per cent of hydraulic cement. It is mixed with oil, and one color (brown) only is made.

LOWE'S METALLIC PAINT, manufactured at Chattanooga, Tenn., is made from red fossiliferous iron ore, mined at Atalla, Ala., and at Ooltewah, Tenn. An analysis of the paint shows its composition to be—

Iron peroxide	78.87
Alumina	3.29
Silica	11.96
Water	5.07
Phosphoric acid, lime, manganese, etc.	.80

The mineral is crushed, then spread on steam-pans and thoroughly dried, passed through buhr mills, bolted, and finally reground.

ROCKY MOUNTAIN VERMILLION is prepared from an ore found near Rawlins, Wyo. The mineral is a hydrated oxide of iron with a fine dark red color, and has the following composition:

Iron peroxide	90.2
Sulphur and lime	1.4
Insoluble matter	7.2
Water	1.2

THE IRON-CLAD PAINT CO., of Cleveland, O., manufacture four varieties of mineral pigments. No. 1, called "Rossie" red, is made from ore mined in Wayne Co., N. Y., and has the following composition:

Iron peroxide	60.50
Alumina	5.68
Calcium carbonate	15.66
Silica	18.00
Moisture	.33

No. 2, or "light brown," is prepared from an ore mined in the iron district of Lake Superior, Mich., and has the following composition:

Iron peroxide	77.25
Alumina	7.00
Calcium carbonate	1 84
Silica	13.84
Loss	.07

No. 3, called "brown purple," is made from an ore coming from the Jackson Mine, Mich., and has the following composition:

Iron peroxide	93.68
Alumina	3.06
Silica	3.20
Sulphur and loss	.06

No. 4, or "brown," is also derived from ore mined in the Lake Superior district.

SLATE PAINTS.—The use of ground slate and similar materials mixed with white lead is quite common. The Indiana Paint and Roofing Co. and the Grafton Paint Co. manufacture a large amount of paint from refuse slate, mixed with other pigments and ground in oil.

SILICATE PAINTS, ASBESTOS PAINTS, etc., are made under patents, and their composition is not generally known.

Varnish.

Varnish is made by dissolving gum or resin in oil, turpentine, or alcohol. In the first case the oil dries, and in the others the turpentine or alcohol evaporates, leaving in either case a film of resin over the surface, smooth, solid, and transparent. The quality of the varnish is determined by the amount of gloss, and its permanence, durability on exposure to the weather, toughness and hardness of the coating, and rapidity of drying.

OIL VARNISHES.—The gums principally used in the preparation of oil varnishes are amber, animé, and copal. The first is hard, tough, and soluble with difficulty, and dries slowly. Animé dries quickly, is nearly as hard and insoluble as amber, but is deficient in toughness, is liable to crack, and turns dark on ex-

posure to light and air. Copal is next in durability to amber, and the paler kinds when made into varnish become lighter on exposure; it is more largely used than any other gum in preparing oil varnishes, animé being frequently added to impart drying qualities.

Linseed oil boiled with substances such as sulphate of lead, etc., for clarifying and imparting drying qualities, is the usual vehicle for oil varnishes; spirits of turpentine is added to the mixture of oil and gum while still hot.

Inferior oil varnishes are made from mixtures of animé, colophony, rosin, litharge, acetate of lead, sulphate of copper, linseed oil and turpentine.

Common rosin dissolved with the assistance of heat in linseed oil or turpentine is frequently mixed with other varnishes to impart brilliancy, but unless sparingly used renders them liable to crack; it is also used as a substitute for the finer varnishes.

Spirit Varnishes are made by dissolving the softer gums, such as mastic, dammar, and common resin, in the best turpentine. They dry more rapidly, are lighter in color, but not so tough and durable as the oil varnishes. They are less costly.

The still softer gums, such as lac (shellac), sandarach, etc., dissolved in alcohol dry quickly, are harder and more glossy than the turpentine varnishes, but are apt to crack and scale off, and will not stand exposure.

Water Varnishes consist of lac dissolved in hot water, mixed with just as much ammonia, borax, potash, or soda as will dissolve the lac. The solution makes a varnish which will just bear washing. The alkalies darken the color of the lac.

Asphalt Varnish is generally made from those varieties of asphaltum which are free from any notable amount of mineral matter, such as glance-pitch and gilsonite. It is a combination of asphaltum, turpentine, and boiled linseed-oil, combined in such proportions or with such additional ingredients as each manufacturer has learned to be desirable, and which he retains as a trade secret. Three of asphaltum to four of boiled oil, with fifteen to eighteen parts of turpentine, is a common formula.

Coal-tar mixed with mineral or fish oil and benzine is frequently substituted for asphalt varnish.

Miscellaneous.

JAPANNING consists in applying successive coats of *japan*, i. e., ordinary lead paint ground in oil and mixed with copal or animé varnish. Each coat is dried in turn at the highest temperature it will bear without melting. The surface is treated with several coats of varnish.

STAINS are liquid preparations of different tints applied to the carefully prepared, smooth, unpainted surface of light-colored wood, such as white pine, in order to give it the appearance of more rare and highly colored woods.

WHITEWASH is pure white lime mixed with water. It should be made of hot lime and applied promptly, as it then adheres better. It will not stand rain for any great length of time, and is easily rubbed off. To prevent cracking and cause the wash to harden, add to every half-bushel of lime 2 pounds sulphate of zinc and 1 pound of common salt.

To produce colors, add to each bushel of lime 4 to 6 pounds of ochre for cream color; 6 to 8 pounds amber, 2 pounds Indian-red, and 2 pounds of lampblack for fawn color; 6 to 8 pounds raw amber and 3 or 4 pounds lampblack for buff or stone color.

WHITING is pure white chalk ground to powder and mixed with water and size (glue). It will not stand exposure to the weather. Proportions, 6 pounds whiting to one quart of strong glue. The whiting is first covered with cold water for six hours, then mixed with size, and left in a cold place until it turns to jelly. It can then be diluted with water and applied.

KALSOMINE is composed of glue, Paris white, and water, colored according to taste and laid on the walls with a brush.

PUTTY is a composition of ground whiting and linseed-oil beaten up into a tough and tenacious cement.

It is used for securing glass in window-sash, and for filling (stopping) crevices and nail-holes in woodwork which is to be painted.

Inspection of Painting.

WOODWORK:—In painting wood the first operation is termed "knotting," that is, covering knots, sap and pitch streaks with shellac dissolved in naphtha or other solvent. Knots and pitch streaks if not killed will cause yellow stains in the finished work. Bad knots should be cut out and a piece of sound wood set in their place. Red lead and glue are sometimes used for killing knots. Hot lime is also used; it is left on the knots for about 24 hours, then scraped off, and the surface coated with shellac.

After knotting, the priming coat is applied. This coat generally contains a large proportion of red lead, which makes it set harder, and gives it the pink color.

The wood must be thoroughly dry, clean, and free from dust and dirt before applying the priming coat.

The object of this coat is to fill the pores of the wood before applying the coloring coats, which otherwise would be absorbed by the wood and wasted.

The priming coat is of the utmost importance, and should be very carefully applied. A poor priming coat under a good finishing is sure to give unsatisfactory results; therefore inferior materials should not be used.

After the priming coat is dry the puttying or stopping of cracks and nail-holes is done. For this purpose the nails are "set in" to the depth of $\frac{1}{8}$ inch or more. After stopping the surface should be rubbed down with sandpaper and well dusted.

The colored and finishing coats are then laid on. Each coat should be thoroughly dry before the next is applied.

Paint should be put on by strokes parallel with the grain of the wood; and long smooth pieces, such as window and door casings, should be finished by drawing the brush carefully along the whole length, so that there may be no breaks in the lines. The brush must be constantly at right angles to the surface being painted, only the ends of the hairs touching it; for only in this manner is the paint forced into the pores of the wood, and at the same time distributed equally. If the brush be held obliquely to the work, it will leave the paint in thick masses wherever it is first applied after being dipped for a fresh supply into the pot, and the surface will be daubed, but not painted.

PLASTER to be painted should be carefully laid, and its surface free from air-bubbles or flaws caused by the "blowing" of the lime.

Special care must be taken that both the plaster and the wall are perfectly dry before they are painted. The surface of the plaster should be thoroughly brushed to remove dust and loose particles.

The surface of plaster is primed with either two or three coats of linseed-oil, red-lead priming, or patent fillers, when the priming is thoroughly dry the colored or finishing coats are applied.

TIN.—In painting tin all traces of oil, grease, and resin must be first removed, and if necessary to secure a clean surface it may be washed with benzine.

IRONWORK.—Before painting wrought iron or steel it is essential that the surface be absolutely free from scale, grease, rust, and moisture. Scale is removed by brushing with stiff wire brushes, and the rust by scraping with steel scrapers, by a sand-blast, or by pickling in diluted acid which is washed off with water.

Rust has the peculiar property of spreading, and extending from a centre, if there is the slightest chance to do so. Hence a small spot of rust on the metal may grow under the surface of the paint, and in time the paint will be flaked off and the metal exposed to the destroying action of oxygen in the presence of water. Therefore close scrutiny is necessary to see that all traces of rust are removed.

Deep-seated rust-spots may be removed by applying heat from a painter's torch, which converts the rust into peroxide of iron, which is harmless and can be easily dusted off.

The adherence of the paint will be increased if the metal is moderately heated before it is primed.

TEST FOR WATER-PROOF PAINT.—Take a small piece of iron and paint it thoroughly with the paint to be tested. After drying place it on a glass plate and wet it with water. Then place a watch-crystal or bell glass over it, making the edges tight with gum or varnish. If the paint is pervious to water, the water will gradually disappear, being decomposed by the iron, the oxygen uniting with the iron to form rust. If the paint is absolutely waterproof the water will remain in the chamber indefinitely.

VARNISHING.—In using varnish great care should be taken to have everything quite clean, washing it if necessary. The cans should be kept corked, the brushes free from oil and dirt, and the work protected from dust or smoke.

Varnish should be applied in very thin coats, laid on in the direction of the fibres of the wood, and sparingly at the angles.

Good varnish should dry so quickly as to be free from stickiness in one or two days. Its drying will be greatly facilitated by the influence of light, but dampness and draughts of cold air must be avoided.

No second or subsequent coat of varnish should be applied until the last is permanently hard; otherwise the drying of the under coats will be stopped.

The time required for this depends not only upon the kind of varnish, but also upon the state of the atmosphere.

Under ordinary circumstances spirit varnishes require from 2 to 3 hours between every coat, turpentine varnishes require 6 or 8 hours, and oil varnishes still longer—sometimes as much as 24 hours.

Oil varnishes are easier to apply than spirit varnishes, in consequence of their not drying so quickly.

The surface of natural wood which is to be varnished should be "filled" before the varnish is applied, to prevent it from being wasted by sinking into the pores of the wood.

Fillers are usually made under patents, and their exact composition is not known. Any gelatinous substance or glue may be used. Flour and starch mixed with water, benzine, or turpentine are frequently used; but the use of these compositions should not be permitted, as they make the wood damp producing mildew, which prevents the varnish from adhering properly.

Varnish applied to painted work is liable to crack if the oil in the paint is not good; also, if there is much oil of any kind in the paint, the varnish hardens more quickly than the paint and forms a rigid skin over it, which cracks when the paint contracts.

The more oil a varnish contains the less liable is it to crack. One pint of varnish will cover about 16 square yards with a single coat.

XI. WATER-SUPPLY.

Materials employed.

The construction of a water-supply system may include any one or all of the materials and methods of construction described in the preceding pages, and the duty of the inspector will be the same as there stated.

Inspection of Cast-iron Pipes.

The cast iron used for the manufacture of pipes is prepared as described under Cast Iron, page 94, and the pipes are cast vertical, for the reasons stated under Notes on Founding, page 96 *et seq.*

The usual requirements for the pipe-metal are that it shall be of gray pig iron, tough, and of such density and texture as will permit of its being easily cut and drilled by hand.

In the foundry inspection the inspector should supervise the preparation of the moulds, the pouring of the metal, the cutting, cleaning, coating, testing, and weighing of all the castings.

After removal from the flasks the pipes should be cleansed, both inside and outside, without the use of acid or other liquid; steel brushes are the best. Then each pipe should be examined for cold-shorts, lumps, swells, scales, blisters, air- and sand-holes, thickness, diameter, depth of hub, and straightness. Hubs should be closely examined for honeycomb. Spigot-ends should be square and of correct size, so they will enter the hubs without chipping.

Cast-iron pipe which appears to the eye to be sound and of proper form may have one or more of the following imperfections:

1. A poor quality of iron.
2. Shrinkage in the metal, due either to improper moulding, varying thickness of the shell, or too rapid cooling of the metal.
3. Want of uniformity in the thickness of the shell, which is usually due to want of care or skill in moulding.

Poor iron may be guarded against by the frequent taking and testing of sample bars. These bars should be taken from every melt and subjected to a transverse test. The dimensions recommended for the test-bars are 26 inches long, 2 inches wide, and 1 inch thick, to be loaded in the centre between supports 24 inches apart (narrow sides vertical); such bars should not break with a less load than 1900 pounds, and should show a deflection of not less than $\frac{25}{100}$ of an inch before breaking. Tensile tests should show from 18,000 to 20,000 pounds per square inch.

Shrinkage strains can only be remedied by proper treatment from the time the iron enters the flask until it is coated and tested.

Pipe should not be stripped and taken from the pit while showing color of heat, for the reason that when the pipe is exposed to a sudden chill from cold air the shrinkage of the outer surface will induce internal strains. Too great stress cannot be laid on this matter of cooling down.

To discover inequality of thickness every pipe should be calipered. The ordinary method is to roll each pipe slowly, and those that do not roll uniformly are calipered.

To insure that the spigots will fit the hubs wrought-iron templets are used for testing the hub and wrought-iron rings for testing the spigot-ends.

TESTING QUALITY OF THE METAL.—The toughness and elasticity of the pipe-metal may be tested by taking sample rings of, say, 1 inch in width and hanging them upon a blunt knife-edge, and then suspending weights from the lower edge at a point opposite to their support, noting their deflections down to the breaking-point; also by letting similar rings fall from known heights upon solid anvils. For testing transverse strength the *beam test* is usually employed.

BEAM TEST.—Test-bars 26 inches long, 2 inches thick, and 1 inch wide are placed narrow edge vertical on supports 24 inches apart and loaded in the middle until broken. The breaking load for this size specimen is about 1900 pounds, and it should show a deflection before breaking of not less than $\frac{25}{100}$ of an inch.

The tenacity of the iron may be tested by submitting it to direct tensile strain in a testing-machine.

COATING THE PIPES.—After being inspected the pipes are coated with some preservative material. The coating known as Dr. Angus Smith's is extensively employed. This coating is a varnish obtained by distilling coal-tar until the naphtha is entir—

removed and the material deodorized. The varnish is used either as it comes from the still or with the addition of 5 or 6 per cent of linseed-oil.

To coat the pipes the varnish is carefully heated in a tank that is suitable to receive the pipes to be coated to a temperature of about 300° F., when the pipes are immersed in it and allowed to remain until they attain a temperature equal to that of the bath.

Another method is to heat the pipes in a retort or oven to a temperature of about 300° F., and then immerse them in the bath of varnish, which is maintained at a temperature of not less than 210° F.

When linseed-oil is mixed with the pitch it has a tendency at high temperature to separate and float upon the pitch. An oil derived from coal-tar by distillation is more frequently substistituted for the linseed-oil in practice. When the pipe is removed from the bath the coating should *fume freely* and be set perfectly hard within one hour from the time of its removal, and should be free from blisters.

The Barff process for preserving iron consists in converting its surfaces into the magnetic or black oxide of iron, which undergoes no change whatever in the presence of moisture and atmospheric oxygen. The pipes are placed in a suitable chamber or oven, and the temperature raised to about 500° F.; steam is then admitted and continued from 5 to 7 hours, at the end of which time the oxidation is complete.

Asphaltum is also used for coating cast-iron, wrought-iron, and steel pipes. The asphaltum used should be neither too brittle nor too oily. It is melted at the necessary temperature, about 250° F., and the pipes dipped. As a test for the quality of the coating, when cold tap it lightly with a hammer; if it adheres like the coating of tin or galvanized iron it is good, but if it comes off in chips the asphaltum employed is too brittle.

HYDRAULIC PROOF OF PIPES.—When the cast pipes have received their preservative coating they are placed in a hydraulic proving-press and tested by water-pressure to the required amount, usually 300 lbs. per sq. in.; and while under such pressure they are smartly tapped all over the surface with a three-pound steel hammer, having a point similar to a pick, attached to a handle 16 inches long. Any failure shown under this test is a cause for rejection.

The pipes which have passed the hydraulic test are weighed, and the weight painted with white paint on the inside of the hub.

LAYING THE PIPE.—The pipes are laid in trenches excavated to the required depth. At the joints the bottom of the trench is excavated to a sufficient depth to permit the calker to reach the bottom of the joint; the trench at this point is also made a little wider to give room for making the joint. Small pipes should be solidly bedded on the bottom of the trench; large pipes are generally laid in wooden cradles, two or three cradles to a length of pipe.

CALKING JOINTS.—To form the joints a gasket made from hemp yarn, oakum, or jute is used, twisted in the form of a rope. This rope should be cut into pieces long enough to go round the pipe and lap a little; it must be well rammed into the hub with a yarning-iron.

Before ramming the yarn in the joint it should be seen that the joint-room is even all round the spigot; if not so the yarner drives one or more cold-chisels into the narrow places so as to crowd the pipe into line.

To guide the molten lead into a joint a "roll" made of ground fire-clay with a yarn-rope centre is used, or a "jointer" made of canvas or rubber faced with steel may be used instead. The roll or jointer is placed around the pipe close to the bell, bringing the two ends on top, and turning them out along the pipe, forming a space called the "pouring-hole." If the joint be wet or very cold it is advisable to pour in a little oil; this prevents the lead from chilling too soon, and prevents the spattering of the lead into the face of the man pouring it.

The lead should be the best quality of soft lead, free from scrap, heated sufficiently to run freely, care being taken not to overheat or burn it during the melting; the furnace should be frequently moved, so that the hot lead need not be carried far enough to give it time to cool.

After the joint is poured and seems full the roll is removed; the joint is examined all around and especially on the bottom to make sure that it is well filled, if not the lead should be cut out and the joint re-poured. Small cavities are sometimes permitted to be filled with cold lead plugs. To put in a plug of cold lead a chisel should be driven into the lead in the joint to form a cavity into which the plug should be driven in the form of a wedge. A plug or band of cold lead should never be placed against a flat surface of lead.

The calking is performed by first cutting off the lump of lead at the pouring-hole, and then driving the chisel lightly between the lead and the surface of the pipe all around. Then, commenc-

ing at the bottom of the joint, the lead is "set up" a little at a time, using first the narrowest calking-iron next to the spigot, then one a size wider, and so on until one is reached which about fills the joint and leaves a smooth surface on the lead. In this way the lead is forced into the recess in the bell and is also thoroughly consolidated near to the spigot.

If the joint was not run full, so that the lead drives away from the reach of the tools, the joint must be run over again, and under no circumstances in a case like this should a cold lead plug be driven in.

TOOLS USED IN CALKING.—The tools used in calking are the "yarning-iron," having an edge about $\frac{1}{16}$ by $\frac{7}{8}$ inch; a "cold-chisel" to cut off the superfluous lead and to start up a tight joint; and from 4 to 10 "sets" or calking-irons, varying from $\frac{1}{16}$ to $\frac{1}{4}$ inch by about $\frac{2}{3}$ of an inch broad at the face. Some calkers prefer those with an offset, others those with a single bend. The hammer should weigh from $1\frac{1}{2}$ to $2\frac{1}{2}$ or 3 lbs., and should not be over 10 inches in length over all.

TESTING THE PIPE.—After the pipes are laid and the joints calked, and before the back-filling is commenced, they are tested under an hydraulic pressure from 25 to 50 per cent greater than that under which they are to be used. The purpose of this test is (1) to detect defective pipes, because in handling the pipe it is liable to receive blows which cause invisible fractures, which may become the source of extensive leaks in use, also in calking the hubs of the pipe may be fractured; and (2) to detect defective workmanship in calking the joints.

The length of pipe tested at one time is usually the distance between stop-valves. The stop-valve acts as the closure for one end, the open end being closed with a blank flange tapped to receive the nozzle of the hose and held in place by wrought-iron screw-clamps which grip the under side of the bell or hub. To provide against drawing of the joints a log of timber fitted with a jack-screw is placed with one end bearing against the centre of the flange, and the other end firmly wedged in the solid earth at the end of the trench.

After the pipes are filled or charged with water an ordinary hand force-pump such as is used to test boilers is connected by a hose to the pipes and worked until the desired pressure is indicated on the gauge. The inspector then examines each pipe, carefully tapping with a light hammer at several points on the surface, and especially at the hubs. A fractured pipe will be

readily detected by the sound emitted. Such defective pipes should be marked to be cut out and replaced by sound ones, after which the test is repeated. The pipes having been found sound, the joints next receive attention; all *sweating* and otherwise defective joints are to be immediately recalked.

Care must be taken before applying the pressure that all the air has been exhausted from the pipe.

BACK-FILLING.—After the pipes are tested the back-filling is commenced. It must be carefully done, all stones being excluded from the layer next the pipe. The earth should be replaced in layers of about 12 inches in depth, and each layer tamped with a rammer weighing about 20 pounds. Surplus earth should be removed and the surface left neatly rounded with sufficient material to allow for settlement.

THICKNESS OF CAST-IRON WATER-PIPES.—There is no standard thickness of cast-iron water-pipe, and the product from different foundries show wide variation. The following table contains the dimensions and weights adopted by a representative foundry.

TABLE 74.

DIMENSIONS AND WEIGHTS OF CAST-IRON WATER-PIPE.

L—Light. M—Medium. H—Heavy. EH—Extra Heavy.

Nominal Internal Diameter	Class.	Thickness.	Lead Room.	Depth of Socket.	Length Laid.	Length Over All.	Breadth of Bell.	Thickness of Belt.	Distance to Edge of Groove.	Length of Groove.	Depth of Groove	Thickness of Bell.	Length of Spigot Bead.	Thickness of Spigot Bead	Total Weight, including Bell of Pipe to Lay 12' 0''.	Weight of Bead.	Weight of Bell.	Weight of Each Additional Inch of Length.
A		B	C	D	E	F	G	H	I	K	L	M	N	O				
3	L	3/8	5/16	4	12' 0''	12' 4''	1 5/16	1 7/16	3/8	1	1/4	7/16	1	1/4	165	.33	17.	1.08
	H	7/16	5/16	4	12 0	12 4	1 3/8	1 9/16	3/8	1	1/4	1/2	1	1/4	196	33	18.	1.33
4	L	3/8	5/16	4	12 0	12 4	1 3/8	1 1/2	3/8	1	1/4	15/32	1	1/4	217	.40	23.5	1.34
	M	7/16	5/16	4	12 0	12 4	1 1/2	1 5/8	3/8	1	1/4	17/32	1	1/4	253	41	24.0	1.59
	H	1/2	5/16	4	12 0	12 4	1 1/2	1 5/8	3/8	1	1/4	19/32	1	1/4	289	42	24 0	1 64
5	L	7/16	5/16	4	12 0	12 4	1 3/8	1 1/2	3/8	1	1/4	1/2	1	1/4	286	.49	26.0	1.90
	M	15/32	5/16	4	12 0	12 4	1 1/2	1 5/8	3/8	1	1/4	9/16	1	1/4	323	.51	26.5	2.06
	H	1/2	5/16	4	12 0	12 4	1 1/2	1 5/8	3/8	1	1/4	9/16	1	1/4	350	.51	27.0	2.24
6	L	7/16	5/16	4	12 0	12 4	1 1/2	1 9/16	3/8	1	1/4	17/32	1	1/4	362	.58	30 5	2.3
	M	1/2	5/16	4	12 0	12 4	1 5/8	1 3/4	3/8	1	1/4	5/8	1	1/4	407	.59	31.0	2.61
	H	17/32	5/16	4	12 0	12 4	1 5/8	1 3/4	3/8	1	1/4	5/8	1	1/4	436	.60	31 0	2.89

8	L	15/32	5/16	4	12 0	12 4	1½	1⅝	⅜	1	¼	19/32	1	¼	500	.75	41.0	3.20
	M	½	5/16	4	12 0	12 4	1⅝	1¾	⅜	1	¼	21/32	1	¼	545	.76	42.0	3.45
	H	9/16	5/16	4	12 0	12 4	1⅝	1¾	⅜	1	¼	21/32	1	¼	610	.76	42.0	3.93
10	L	15/32	5/16	4	12 0	12 4	1⅝	1¾	⅜	1	¼	⅝	1	¼	635	.91	58	4.00
	M	½	5/16	4	12 0	12 4	1¾	1¾	⅜	1	¼	23/32	1	¼	677	.92	59	4.29
	H	19/32	5/16	4	12 0	12 4	1¾	1¾	⅜	1	¼	23/32	1	¼	800	.93	59	5.14
12	L	9/16	5/16	4	12 0	12 4	1⅝	1¾	⅜	1	¼	11/16	1	¼	900	1.75	74	5.79
	M	⅝	5/16	4	12 0	12 4	1¾	1⅞	⅜	1	¼	27/32	1	¼	1005	1.80	75	6.44
	H	23/32	5/16	4	12 0	12 4	1¾	1⅞	⅜	1	¼	27/32	1	¼	1147	1.80	75	7.5
14	L	19/32	5/16	4	12 0	12 4	1⅝	1¾	⅜	1	¼	27/32	1	¼	1150	1.85	108	7.09
	H	¾	5/16	4½	12 0	12 4½	1¾	1⅞	⅜	1	¼	29/32	1	¼	1237	1.90	110	7.81
16	L	⅝	5/16	4	12 0	12 4	1¾	1⅞	⅜	1	¼	¾	1	¼	1360	2.00	136	8.49
	H	25/32	5/16	4½	12 0	12 4½	1¾	2	⅜	1	¼	15/16	1	¼	1678	2.10	140	10.7
18	L	11/16	⅜	4	12 0	12 4	1¾	1⅞	⅜	1	¼	13/16	1	¼	1680	2.2	167	10.5
	H	13/16	⅜	4½	12 0	12 4½	1⅞	2⅛	⅜	1	¼	15/16	1	¼	1964	2.3	170	12.4
20	L	23/32	⅜	4	12 0	12 4	1⅞	2	⅜	1	¼	27/32	1	¼	1958	2.5	199	12.1
	M	25/32	⅜	4½	12 0	12 4½	1⅞	2⅛	⅜	1	¼	31/32	1	¼	2112	2.6	202	13.25
	H	27/32	⅜	4½	12 0	12 4½	1⅞	2⅛	⅜	1	¼	31/32	1	¼	2274	2.7	207	14.35
24	L	13/16	⅜	5	12 0	12 5	2	2¼	⅜	1	¼	31/32	1	¼	2500	2.95	235	16.4
	M	⅞	⅜	5	12 0	12 5	2	2⅛	⅜	1	¼	1 3/32	1	¼	2750	3.00	240	17.75
	H	15/16	⅜	5	12 0	12 5	2	2⅛	⅜	1	¼	1 3/32	1	¼	3000	3.10	240	19.1
30	L	27/32	7/16	5	12 0	12 5	2	2½	⅜	1	¼	1 1/16	1	¼	3100	3.35	308	19.4
	M	30/32	7/16	5	12 0	12 5	2	2¾	⅜	1	¼	1 1/16	1	¼	3700	3.35	310	22.1
	H	1 1/16	7/16	5	12 0	12 5	2⅛	2⅝	⅜	1	¼	1 7/32	1	¼	4200	3.6	364	26.6
	EH	1⅛	7/16	5	12 0	12 5	2⅛	2⅝	⅜	1	¼	1 7/32	1	¼	4600	3.6	364	29.4
36	L	⅞	7/16	5	12 0	12 5	2	2½	⅜	1	¼	1⅛	1	¼	4200	3.95	402	26.3
	M	15/16	7/16	5	12 0	12 5	2⅛	2¾	⅜	1	¼	1¼	1	¼	4600	3.95	440	28.8
	H	1 1/16	7/16	5	12 0	12 5	2⅛	2¾	⅜	1	¼	1 7/16	1	¼	5000	4.00	465	31.5
	EH	1 3/16	7/16	5	12 0	12 5	2⅛	2¾	⅜	1	¼	1 7/16	1	¼	5600	4.00	465	35.6
42	L	1 1/16	7/16	5	12 0	12 5	2⅛	2⅝	⅜	1	¼	1 5/16	1	¼	6000	4.5	560	37.75
	M	1 3/16	7/16	5	12 0	12 5	2⅛	2⅞	⅜	1	¼	1⅜	1	¼	7000	4.7	570	45.4
	H	1 5/16	7/16	5	12 0	12 5	2⅛	2⅞	⅜	1	¼	1½	1	¼	8000	4.7	580	51.5
48	L	1¼	7/16	5	12 0	12 5	2⅛	2¾	⅜	1	¼	1 7/16	1	¼	8000	5.3	685	50.7
	M	1 5/16	7/16	5	12 0	12 5	2⅛	3	⅜	1	¼	1⅝	1	¼	8700	5.5	690	55.6
	H	1⅜	7/16	5	12 0	12 5	2⅛	3	⅜	1	¼	1¾	1	¼	9400	5.5	698	60.5
60	L	1 5/16	½	5	12 0	12 5	2¼	3	⅜	1	¼	1⅞	1	¼	10000	6.5	800	63.8
	H	1¾	½	5	12 0	12 5	2⅜	3⅛	⅜	1	¼	2 1/16	1	¼	15000	6.8	900	97.8

TABLE 75.

SIZE AND WEIGHT OF STANDARD SPECIALS (APPROXIMATE).

Crosses.

in.	lbs.
2	40
3	104
3x2	90
4	150
4x3	114
4x2	110
6	200
6x4	150
6x3	150
8	325
8x6	265
8x4	265
8x3	225
10	510
10x8	415
10x6	388
10x4	338
10x3	350
12	700
12x10	650
12x8	615
12x6	540
12x4	525
12x3	495
14x10	750
14x8	635
14x6	570
16	1085
16x14	1070
16x12	1025
16x10	1010
16x8	825
16x6	790
16x4	650
20	1790
20x12	1370
20x10	1225
20x8	1000
20x6	1000
20x4	1000
24	2190
24x20	2020
24x6	1340
30x20	2635
30x12	2250
30x8	1995

Tees.

in.	lbs.
2	28
3	76
3x2	76
4	100
4x3	90
4x2	87
6	150
6x4	130
6x3	125
6x2	120
8	266
8x6	252
8x4	222
8x3	220
10	390
10x8	390
10x6	312
10x4	292
10x3	290
12	565
12x10	510
12x8	492
12x6	484
12x4	460
14x12	650
14x10	650
14x8	575
14x6	545
14x4	525
14x3	490
16	790
16x14	850
16x12	825
16x10	890
16x8	755
16x6	630
16x4	655
20	1875
20x16	1115
20x12	1025
20x10	1090
20x8	900
20x6	875
20x4	845
21x10	1465
24	1875

Tees.

in.	lbs.
24x12	1425
24x8	1375
24x6	1375
30	3025
30x24	2640
30x20	2200
30x12	2085
30x10	2050
30x6	1825
36	5140
36x30	4200
36x12	4050

45° Branch Pipes.

in.	lbs.
3	90
6x6x4	145
8	200
8x6	290
24	2765
24x24x20	2145
30	4170
36	10300

Sleeves.

in.	lbs.
2	10
3	20
4	44
6	65
8	86
10	140
12	176
14	208
16	340
20	500
24	710
30	965
36	1500

90° Elbows.

in.	lbs.
2	14
3	34
4	48
6	110
8	145
10	225
12	370
14	450
16	525
20	900
24	1400

1/8 or 45° Bends.

in.	lbs.
3	30
4	65
6	85
8	160
10	190
12	290
16	510
20	740
24	1425
30	2000

1/16 or 22½° Bends.

in.	lbs.
6	150
8	155
10	165
12	260
16	500
24	1280
30	1735

Reducers.

in.	lbs.
3x2	35
4x3	42
4x2	40
6x4	95
6x3	80
8x6	126
8x4	116
8x3	116
10x8	212
10x6	150
10x4	128
12x10	278
12x8	254
12x6	250
12x4	250
14x12	475
14x10	430
14x8	340
14x6	285
16x12	475
16x10	435
20x16	690
20x14	575
20x12	540
20x8	300
24x20	745
30x24	1305
30x18	1385
36x30	1730

Plugs.

in.	lbs.
2	2
3	5
4	8
6	12
8	26
10	46
12	66
14	70
16	100
20	150
24	185
30	370

Cap.

in.	lbs.
3	15
4	25
6	60
8	75
10	100
12	120

Drip-boxes.

in.	lbs.
4	235
8	355
10	760
20	1420

TABLE 76.

WEIGHT OF LEAD AND GASKET REQUIRED FOR EACH JOINT OF CAST-IRON PIPE (WATER).

Diameter.	Gasket.	Lead.	Diameter.	Gasket.	Lead.
Inches.	Lbs.	Lbs.	Inches.	Lbs.	Lbs.
2	0.050	3¼	18	.75	33
3	.075	4¾	20	1.00	37
4	.115	8	24	1.25	45
6	.175	13	30	1.75	60
8	.25	16	36	2.50	80
10	.30	18	40	3.00	95
12	.35	22	42	4.00	105
14	.42	25	48	5.00	145
16	.45	29	60	7.00	191

As the diameter and depth of the hubs vary, the above weights are only approximate.

Inspection of Steel Pipe.

The plates used for pipe-making are usually of "shell" steel, such as is used in boiler-work. They are subjected to the same scrutiny for surface imperfections and tests for strength as steel employed for boiler-making.

The thickness should be ascertained by carefully calipering the edges and centre of each plate, and those falling below the tolerance allowed by the specifications rejected.

The drifting test applied is that the plates must stand the punching and enlarging to one-third their original diameter of a row of holes ¾ inch in diameter, pitched 1¼ inches between centres, and two diameters from the edge of the plate, without cracking.

The plates must be sufficiently tough and pliable to allow cold-scarfing to a fine edge at the laps without cracking, and to be rolled to the circle of the pipe without cracking between rivet-holes and the edge of the plate.

The shop-driven rivets are usually of steel, the field rivets of double-refined iron.

The joints are made telescopic.

The seams are bevelled and hammer-calked until water-tight, without packing or plugs.

The finished pipe is scraped and thoroughly cleaned from scale, etc., and inspected.

The outlets are formed with flanged iron castings riveted to the pipe, lead gaskets being used to secure a water-tight joint when bolts are used to fasten them.

The examination of the riveting should be performed as directed under Inspection of Rivets, page 194.

COATING THE PIPES.—The pipes are coated with coal-tar, asphaltum, or one of the many patented coatings, by immersing them in a bath of suitable size and allowing them to remain long enough to attain the temperature of the coating mixture (usually 250° F.). They are then withdrawn, the coating allowed to stiffen for about 15 minutes, and then again immersed for a short time to thicken the coat.

After the coating is satisfactorily finished the pipes are subjected to a hydraulic test of the required pressure. If any leaks show they are recalked, recoated, and retested until each section is water-tight at the prescribed pressure,

ASPHALT AND COAL-TAR COATING.—This coating is composed of natural asphaltum and coal-tar in the proportion of about four of asphaltum to one of coal-tar. The asphaltum should be free from petroleum residuum, and the coal-tar should be deodorized and free from oily or greasy substances. The ingredients are placed in a tank of suitable size and boiled and stirred until fluid by the application of either direct or indirect heat; the latter is preferable.

TESTING THE COATING.—The fitness of the asphalt, asphalt and coal-tar, or patented coating is tested by immersing in the boiling mass a piece of ⅜-inch steel not less than 6 inches square, and allowing it to remain for 10 minutes; it is then removed and immediately cooled in ice-water; it is then struck smartly with a light hammer: if the coating cracks it indicates that it is too brittle; if it does not crack the specimen is subjected to a temperature of 100° F; if it softens it is too soft. If the coating withstands all of these tests and adheres firmly to the steel surface it may be considered satisfactory; if not it must be suitably altered.

The quality of the coating-varnish must be frequently tested, and fresh materials added from time to time to keep it of the proper consistency.

LAYING THE PIPE.—The sections as they come from the shop are riveted in pairs on the banks of the trench, then rolled on to

skids placed across the trench, and raised in slings by tripod derricks sufficiently to allow the removal of the skids. They are then lowered into the trench, pinched up, and bolted to the last section laid. The rivets in the upper side of the joints are then driven from the outside, a man inside the pipe "holding on." The rivets in the lower sides and bottom of the joints are then driven by men inside the pipe working on their knees with short-handled hammers.

At every other joint a 1¼-inch tapped hole is left in the top of the pipe, or hand-hole castings are placed near the rivet line, through which the outside-driven rivets are passed to the holder on the inside; when the joint is finished the hole is closed with a cast-iron plug or plate.

Pieces of heavy burlap are spread on and in the pipe for the men to walk and stand upon, and after everything else is completed every bruised or scratched part of the inner and outer pipe-surface is carefully coated with asphalt paint.

The back-filling, etc., is carried out in the same manner as previously described under Cast-iron Pipe, page 359.

Valves and Hydrants.

VALVES are examined for quality of material and workmanship. They are subjected to the required hydraulic pressure test, and while under pressure the bodies are tested with the hammer in the same manner as cast-iron pipe. The spindles, stuffing-boxes, disks, and valves are examined for quality of metal and workmanship.

HYDRANTS are examined for quality of material and workmanship.

SETTING VALVES AND HYDRANTS.—Care must be taken to set valves and hydrants vertical; before setting they should be carefully examined and all sand or dirt should be cleaned out, especially from around the valve-seats. Hydrants should have gravel or broken stone placed around them for 1 foot below their base to 1 foot above the drip. Valve-boxes should be placed at each valve and the earth well tamped around them.

XII. SEWERAGE.

Materials employed for Sewers.

The materials used in the construction of sewers are vitrified-clay pipe, cement-concrete pipe, brick, stone, concrete, timber, etc. The quality of the several materials should be the same as described in the preceding pages under Structural Materials.

VITRIFIED PIPE is made from clay and salt glazed. The pipes are moulded by machinery, dried, and placed in a close kiln and gradually subjected to an intense heat.

SALT-GLAZE.—When the temperature is sufficient coarse salt is thrown upon the fire in small quantities; a portion of the salt vaporizes, which vapor, combining with the silica in the clay, produces a soda-salt or glass, which is a glaze and forms part of the body of the pipe.

SLIP-GLAZE is considered to be inferior to salt-glaze. It is applied as follows: After the pipes are made and dried they are dipped into a solution of argillaceous earth or aluminous clay mixed to about the consistency of cream. After dipping, the pipes are placed in the kiln and burned; the heat fuses the clay, thus producing a smooth glazed surface. The slip-glaze is apt to peel off when the pipe is subjected to the action of acids or frost.

If the glaze can be picked off with a knife it is an indication that the pipes are made from a clay that would not stand the high temperature required for salt-glazing, and are therefore probably slip-glazed.

The vitrified pipes should be examined (1) to see that they are straight and not warped out of line; (2) that the bore is uniform from end to end; (3) that they are sound; (4) that they are well burned and that the glaze is uniform on both the interior and exterior surfaces; (5) that the interior is free from lumps and blisters; (6) that the hub and body of the pipe are free from fire-checks, cracks, and flaws.

Each pipe as it is passed to the pipe-layer should be closely examined to make sure that none which may have been injured since the formal examination are laid in the trench.

In laying the pipes the spigot-end of the pipe should be laid downhill.

PIPES OF CONCRETE should meet the same requirements as vitrified-clay pipes, and in addition they should be thoroughly seasoned, as green pipes are liable to collapse when the weight of the earth comes upon them. A well-seasoned, sound cement pipe when struck a smart blow with a light hammer emits a clear metallic sound.

TESTS FOR PIPE.—The tests applied to ascertain the fitness of pipes for sewers are (1) a test for permeability; (2) resistance to crushing; (3) ability to withstand the action of chemicals.

The test for permeability is made by first drying the pipe till it ceases to lose weight, and then submerging it in water, allowing it to remain at least 24 hours under water, then removing it from the water, wiping dry, and reweighing. The amount of moisture absorbed ranges from 0 to 7 per cent.

The impermeability of a pipe may also be tested by closing one end of the pipe with some suitable substance, then reversing it and filling it with water. If the material is not perfectly impervious it will soon be detected by the sweating of the pipe, as it is termed, or the appearance of water oozing on the outside, together with the loss of water from the interior of the pipe.

The power to resist chemical action may be tested by pulverizing a piece of the pipe and boiling it in hydrochloric acid, washing on a filter, and noting loss of weight.

To ascertain the resistance of the pipes to crushing they may be placed in a hydraulic press and pressure applied in the usual way.

The capability to resist shocks may be ascertained by dropping a known weight from a given height, the percussive action being equal to the velocity multiplied by the weight. If a weight of 14 lbs. be used and dropped from the following heights the percussive force will be as stated:

4 inch	fall	=	64.65 lbs.
5 "	"	=	72.47 "
6 "	"	=	79.38 "
7 "	"	=	85.74 "

The record of this test would appear as follows:

Kind of pipe......... Diameter......... Weight.........
Number of pieces when broken........

Remarks: After........blows with 4-inch fall pipe (perfect) (cracked) (broken).

MAN-HOLES are shafts of brick masonry built up from the sewer to the surface of the street, of sufficient size for the entrance of a man, for the purpose of inspection and cleansing. The usual form of man-hole is circular or elliptical at the base, and tapering upwards to near the surface of the street, where it receives the cast-iron frame and cover.

LAMP HOLES are small shafts, usually formed of lengths of 6-inch pipe, built up vertically from the sewer to the surface of the street, and there covered with a cast-iron frame and cover. The purpose of lamp-holes is for the introduction of a lamp to illuminate the interior of the sewer for examination.

FLUSH TANKS are chambers of brick masonry, furnished with siphons which automatically and periodically empty the chamber, and thus cause a sudden and copious dash of water to flow through the sewer and cleanse it. They are usually supplied with water from the street-mains through an ordinary service-pipe of small size, and the admission of the water is controlled by an ordinary lever-handle stop-cock.

Inspection of Sewer Construction.

The inspector should be constantly present and watchful. His first duty will be to inspect the quality and dimensions of the material furnished; second, to see that the trenches are properly excavated, sheathed, and braced; and third, to see that the sewer is properly built and to the grades and lines given by the engineer.

PIPE SEWERS.—Examine each pipe for size, thickness, depth of socket, shape, fire-cracks, and blisters; for soundness, by testing each pipe by its ring immediately before lowering into the trench. A pipe that does not give a perfectly ringing sound when struck with a light hammer should be rejected.

See that the pipe is laid true to grade and line, that each length is properly bedded. For this purpose a recess should be cut in the bottom of the trench to receive the socket of the pipe; otherwise the pipes will be supported by the sockets only.

That the spigot-end of each pipe is properly entered and sent home in the socket of the adjoining pipe.

That the gasket of hemp or oakum is properly used. The socket should not be filled with it to the exclusion of the mortar.

That the Y branches are laid according to plan, and their ends, if not immediately connected, closed with a suitable stopper.

That the cement is properly mixed and the joints carefully filled with it all round the pipe. Examine the bottom of the joints to see that this is done; also see that mud is not used in place of cement.

See that no mortar passes into the interior of the pipe. If it does the gaskets have not been properly packed.

That man-hole foundations are firm and substantial; that the junctions of lateral sewers in the man-holes are built in a smooth and workmanlike manner; the bottoms of the man-holes formed to the shape required by the plans; the head of the pipes entering the walls are cut in good shape; that the walls are carried up to the surface in a symmetrical and smooth manner; that the iron steps are built in as required; that the walls are plastered as called for in the specifications.

That the joints after being cemented are not disturbed until filled around and over and tamped. The back-filling should be carefully done. No stones should be used for filling within a foot of the pipe. That the filling is carefully placed in the trench—not thrown in violently—and tamped with suitable tampers until the material fills the trench solidly.

That the surface of the ground is left in good condition for travel.

Brick Sewers.—Examine the bricks for quality; select the hardest and smoothest for invert and sides.

Examine foundation and see that timber or other material is properly placed and secured.

See that profiles and centres are properly set and of sufficient strength.

Examine quality of cement and sand; see that the mortar is properly mixed and of the required proportions.

Have the bricks well wet in dry weather and not too wet in damp weather.

Watch the masons to see that they lay each brick to line with a full mortar bed and joint, and without unnecessary pounding or pushing after it is in place.

See that the joints are of such thickness that a full number of courses of brick can be used without splitting a course.

If plastering the exterior is required see that it is properly executed and not injured during the back-filling.

That man-holes are formed and built symmetrically of the dimensions required, steps built in, and exterior plastered.

That slants and junctions are properly located and well built in and exterior ends closed with stoppers.

Interior of sewer cleaned of loose cement, brick-chips, and other rubbish.

If water is met in the trench care must be used to keep it away from the brickwork until the cement is set.

If the lower course of sheathing is to be withdrawn it should be drawn above the crown of the arch before filling in; if it is left to be drawn afterwards there is danger that a crack will be caused in the brickwork.

Back-filling to be carefully done and thoroughly rammed, and surface left in good condition.

Table 77.

LENGTH OF SEWER-PIPE ONE BARREL OF CEMENT WILL LAY.

Diameter of Pipe. Inches.	Length. Feet.	Diameter of Pipe. Inches.	Length. Feet.
6	1200	15	190
8	666	18	130
10	426	20	106
12	300	24	74

Table 78.

WEIGHT OF SALT-GLAZED SEWER-PIPE.

Diameter. Inches.	Weight per Foot. Pounds.	Diameter. Inches.	Weight per Foot. Pounds.
2	5	15	62
3	7	16	72
4	10	18	84
5	13	20	109
6	16	21	118
8	24	22	122
9	28	24	136
10	31	27	230
12	42	30	270
14	60	36	360

XIII. Paving.

Materials employed.

The materials used for pavements are stone in the form of blocks and broken fragments, wood in the form of blocks and plank, asphalt in two forms—sheet and block, and clay in the form of brick.

The stones employed are granite, trap, sandstone, and limestone.

Granite-block Paving.

Manufacture of Granite Paving-blocks.—The manufacture of paving-blocks varies in many details from the ordinary methods of granite-cutting. The high skill and fine workmanship of the stone-cutter are not needed, but a quickness in seeing and taking advantage of the directions of cleavage, as well as a deftness in handling the necessary tools, is requisite.

The tools used for making the blocks are knapping-hammers, opening-hammers, reels, chisels, and, for the initial splits, drills, wedges, and half-rounds. When the block-maker quarries his own stock it is called "motion-work," and the same process is used as in quarrying stone for other purposes, except that, as large blocks are not required, most of it can be done with plug and feather. Slabs, having been split out in the usual manner to sizes that may be easily turned over and handled by one man, are subdivided into pieces corresponding approximately to the dimensions of the required blocks. This is done by striking repeated blows upon the rock along the line of the desired break with knapping and opening-hammers. When a break is to be made crosswise the grain it is frequently necessary to chisel a light groove across the face, and commonly across the adjacent sides, to guide the fracture produced by striking on the opposite surface with the opening-hammer. Good splits can, however, be made along either the rift or grain by the skilful use of the opening-hammer alone. Blocks broken out in the manner described are trimmed

and finished with the reel, which is a hand-hammer having a long, flat steel head attached to a short handle.

Inspection of Granite-block Paving.

As soon as the blocks are brought upon the work they must be inspected (1) as to their quality, (2) character of the dressing, and (3) as to their dimensions.

The requirements of the specifications under which the work is being executed must be the guide for the acceptance or rejection of the blocks. In general it may be said, Reject all stones which are easily chipped by a smart blow with a light hammer. Rough and ill-shaped blocks should not be permitted in first-class work.

When stone is brought from more than one quarry, that from each quarry should be piled and laid in separate sections of the work.

In laying the blocks see that those for each course are selected with regard to uniformity of depth and width, and that the longitudinal joints are broken by a lap of at least two inches.

The ramming of the blocks requires close watching to see that it is properly done, and that every block is brought to a solid bearing.

The practice of the workmen is invariably to use the rammer so as to secure a fair surface without any regard to the bearing of the blocks. The result of such surfacing process is to produce an unsightly and uneven roadway when the pressure of traffic is brought upon it. The rammer should weigh not less than 50 pounds and have a diameter of not less than 3 inches.

When the joints are to be filled with paving-pitch the operation must be closely scrutinized to see that the required quantity is poured into the joints, and neither spilled over the surface of the pavement nor removed unused.

Paving-pitch.

The bituminous material employed for filling the joints in paving is the tar produced in the manufacture of gas, which, when redistilled, is called *distillate*, and is numbered 1, 2, 3, 4, etc., according to its density; it is used alone and in combination with asphaltum, creosote, etc.

The formula for the bituminous joint-filling used in New York City is:

Refined Trinidad asphaltum.................	20	parts
No. 4 coal-tar distillate.......................	100	"
Residuum of petroleum.......................	3	"

The mode of applying the paving-pitch is as follows:

After the blocks are rammed the joints are filled to a depth of about two inches with clean gravel heated to a temperature of about 250° Fahr. Then the hot pitch is poured in until it forms a layer of about an inch on top of the gravel, then more gravel is filled in to a depth of about two inches and more pitch poured in until it appears on top of the gravel, then gravel is filled in until it reaches to within half an inch of the top of the blocks; this remaining half inch is filled with pitch, and then fine gravel or sand is sprinkled over the joint.

In some cases the joints are first filled with the heated gravel, then the cement poured in until the joints are filled flush with the top of the pavement. This method is open to objection, for if the gravel is not sufficiently hot the pitch will be chilled and will not flow to the bottom of the joint, but instead will form a thin crust near the surface, which, under the action of frost and the vibration of traffic, will be quickly cracked and broken up; the gravel will settle and the blocks will be jarred loose, and the surface of the pavement will become a series of ridges and hollows.

In heating the pitch care must be exercised that it is not *coked*, in which condition it is brittle and useless.

The gravel is heated either in revolving cylinders or in rectangular iron pans supported on piles of stones with a fire underneath. The same apparatus is employed for drying sand when it becomes necessary to remove moisture.

Trap, sandstone, and limestone blocks are laid in the same manner as described above for granite blocks.

All the stone-block pavements are laid either on a bed of clean sand or on a layer of concrete.

Wood Pavements.

Wood pavements are formed of either rectangular or cylindrical blocks of wood. The rectangular blocks are generally 3 inches wide, 9 inches long, and 6 inches deep; the round blocks are commonly 6 inches in diameter and 6 inches long

The kinds of wood used are cedar, cypress, juniper, yellow pine, mesquite, and recently *jarrah* from Australia and *pyingado* from India have been used.

The wood is used in its natural condition or impregnated with creosote or other chemical preservative.

The blocks of wood are laid either on the natural soil, on beds of sand and gravel, on a layer of broken stone, on a layer of concrete, or sometimes on a double layer of plank, in the same manner as described under Granite Paving. The joints are filled either with sand or paving-pitch or Portland cement grout.

Asphalt Pavements.

ASPHALTIC PAVING MATERIALS.—All asphaltic or bituminous pavements are composed of two essential parts, namely, the cementing material (matrix) and the resisting material (aggregate). Each has a distinct function to perform: the first furnishes and preserves the coherency of the mass; the second resists the wear of the traffic.

Two classes of asphaltic paving compounds are in use, namely, *natural* and *artificial*. The natural variety is composed of either limestone or sandstone naturally cemented by bitumen. To this class belong the bituminous limestones of Europe, Texas, Utah, etc., and the bituminous sandstones of California, Kentucky, Texas, Indian Territory, etc. The artificial consists of mixtures of asphaltic cement manufactured, as described on page 49 *et seq.*, with sand and stone-dust. To this class belong the pavements made from Trinidad, Bermudez, Cuban, and similar asphaltums. For the artificial variety most of the hard bitumens are, when properly prepared, equally suitable. For the aggregate the most suitable materials are stone-dust from the harder rocks, such as granite, trap, etc., and sharp angular sand. These materials

should be entirely free from loam and vegetable impurities. The strength and enduring qualities of the mixture will depend upon the quality, strength, and proportion of each ingredient, as well as upon the cohesion of the matrix and its adhesion to the aggregate.

BITUMINOUS LIMESTONE consists of carbonate of lime naturally cemented with bitumen in proportions varying from 80 to 93 per cent of carbonate of lime and from 7 to 20 per cent of bitumen. Its color when freshly broken is a dark (almost black) chocolate-brown, the darker color being due to a larger percentage of bitumen. At a temperature of from 55° to 70° F. the material is hard and sonorous and breaks easily with an irregular fracture ; at temperatures between 70° and 140° F. it softens, passing with the rise in temperature through various degrees of plasticity, until, at between 140° and 160° F., it begins to crumble, at 212° F. it commences to melt, and at 280° F. it is completely disintegrated. Its specific gravity is about 2.235.

Bituminous limestone is the material employed for paving purposes throughout Europe. It is obtained principally from deposits at Val-de-Travers, canton of Neufchâtel, Switzerland; at Seyssel, in the department of Ain, France; at Ragusa, Sicily; at Limmer, near Hanover; and at Vorwohle, Germany.

Bituminous limestone is found in several parts of the United States. Two of these deposits are at present being worked, one in Texas, the material from which is called "lithocarbon," and one on the Wasatch Indian Reservation. These deposits contain from 10 to 30 per cent of bitumen.

The bituminous limestones which contain about 10 per cent of bitumen are used for paving in their natural condition, being simply reduced to powder, heated until thoroughly softened, then spread while hot upon the foundation, and tamped and rammed until compacted.

BITUMINOUS SANDSTONES are composed of sandstone rock impregnated with bitumen in amounts varying from a trace to 70 per cent. They are found both in Europe and America. In Europe they are chiefly used for the production of pure bitumen, which is extracted by boiling or macerating them with water. In the United States extensive deposits are found in the Western States, and since 1880 they have been gradually coming into use as a paving material, and now upwards of a hundred and fifty miles of streets in Western cities are paved with them. They are prepared for use as a paving material by crushing to powder, which

is heated to about 250° F. or until it becomes plastic, then spread upon the street and compressed by rolling; sometimes sand or gravel is added, and it is stated that a mixture of about 80 per cent of gravel makes a durable pavement.

TRINIDAD ASPHALTUM.—The deposits of asphaltum in the island of Trinidad, W. I., have been the main source of supply for the asphaltum used in street-paving in the United States. Three kinds are found there, which have been named, according to the source, *lake-pitch*, *land-* or *overflow-pitch*, and *iron-pitch*. The first and most valuable kind is obtained from the so-called Pitch Lake.

The term *land-* or *overflow*-pitch is applied to the deposits of asphaltum found outside of the lake. These deposits form extensive beds of variable thickness, and are covered with from a few to several feet of earth; they are considered by some authorities to be formed from pitch which has overflowed from the lake, by others to be of entirely different origin. The name *cheese-pitch* is given to such portions of the land-pitch as more nearly resemble that obtained from the lake.

The term *iron-pitch* is used to designate large and isolated masses of extremely hard asphaltum found both within and without the borders of the lake. It is supposed to have been formed by the action of heat caused by forest fires which, sweeping over the softer pitch, removed its more volatile constituents.

The name *épurée* is given to asphaltum refined on the island of Trinidad. The process is conducted in a very crude manner in large, open, cast-iron sugar-boilers.

THE CHARACTERISTICS OF CRUDE TRINIDAD ASPHALTUM, both *lake* and *land*, are as follows: It is composed of bitumen mixed with fine sand, clay, and vegetable matter. Its specific gravity varies according to the impurities present, but is usually about 1.28. Its color when freshly excavated is a brown, which changes to black on exposure to the atmosphere. When freshly broken it emits the usual bituminous odor. It is porous, containing gas-cavities, and in consistency it resembles cheese. If left long enough in the sun the surface will soften and melt and will finally flow into a more or less compact mass. The average composition of both the land and lake varieties is shown by the following analyses:

AVERAGE COMPOSITION OF TRINIDAD ASPHALTUM.

Constituents.	Lake.		Land.
	Hard.	Soft.	
	Per Cent.	Per Cent.	Per Cent.
Water	27.85	34.10	26.62
Inorganic matter	26 38	25.05	27.57
Organic non-bituminous matter	7.63	6.35	8.05
Bitumen	38 14	34.50	37.76
	100.00	100.00	100.00
When the analyses are calculated to a basis of dry substances the composition is: Inorganic matter	36.56	38.00	37.74
Organic matter not bitumen	10.57	9.64	10.68
Bitumen	52.87	52.36	51.58
	100.00	100.00	100.00
The substances volatilized in 10 hours at 400° F	3.66	12.24	0.86 to 1.37
The substances soften at	190° F	170° F.	200° to 250° F.
" " flow at	200° F.	185° F.	210° to 328° F.

Refined Trinidad Asphaltum.—The crude asphaltum is refined or purified by melting it in iron kettles or stills by the application of indirect heat.

The operation of refining proceeds as follows: During the heating the water and lighter oils are evaporated, the asphaltum is liquefied, the vegetable matter rises to the surface and is skimmed off, the earthy and silicious matters settle to the bottom, and the liquid asphaltum is drawn off into old cement- or flour-barrels.

When the asphaltum is refined without agitation the residue remaining in the still forms a considerable percentage of the crude material, frequently amounting to 12 per cent, and it was at one time considered that the greater the amount of this residue the better the quality of the refined asphaltum; but since agitation has been adopted the greater part of the earthy and silicious matters is retained in suspension and it has come to be considered just as desirable for a part of the surface mixture as the sand which is subsequently added. The refined asphaltum, if for local use, is generally converted into cement in the same still in which it was refined.

The Characteristics of Refined Trinidad Asphaltum are as follows:

The color is black with a homogeneous appearance. At a tem-

perature of about 70° F. it is very brittle and breaks with a conchoidal fracture; it burns with a yellowish-white flame, and in burning emits an empyreumatic odor, and possesses little cementitious quality; to give it the required plasticity and tenacity it is mixed while liquid with from 16 to 21 pounds of residuum oil to 100 pounds of asphaltum in the manner described on page 49 *et seq.*

The product resulting from the combination is called ***asphalt paving-cement;*** its consistency should be such that, at a temperature of from 70° to 80° F., it can be easily indented with the fingers and on slight warming be drawn out in strings or threads.

AVERAGE COMPOSITION OF REFINED TRINIDAD ASPHALTUM.

	Lake.	Land.
Specific gravity at 77° F	1.38	1.42
	Per Cent.	Per Cent.
Bitumen	56.29	53.75
Organic matter not bituminous	8.05	8 01
Inorganic matter	35.66	38.24
	100.00	100.00
Bitumen soluble in petroleum naphtha	41.43	35.22
Per cent of total bitumen soluble	73.60	65.32
Softens at	190° F.	210° F.
Flows at	205° F.	230° F.

BERMUDEZ ASPHALT.—This is the name given to the asphaltum obtained from a lake or deposit situated in the State of Bermudez, Venezuela. The crude asphaltum is of the same variety as the Trinidad, namely, bitumen mixed with sand, clay, and vegetable matter; its average specific gravity is 1.09, and its average composition is as follows:

	Per Cent.
Bitumen	93 54
Mineral matter	2.16
Organic matter not bituminous	1.15
Water	3.15
	100.00
Petrolene	77.90
Asphaltene	21.08
Retine	1.02
	100 00

The refining process is practically similar to that described under Trinidad Asphaltum, but is much more rapid, owing to the small amount of water and mineral matter present. In manufacturing the cement it requires much less petroleum residuum than the Trinidad on account of the large amount of oil that it contains; it melts at a lower temperature than the Trinidad, and the following are some of its characteristics: at 60° F. compressible; at 70° F. viscous and malleable; at 100° F. flowing and can be stretched in hair-like threads; at 189° F. melts; at 400° F. gives no flash.

CALIFORNIA ASPHALTUM.—Asphaltum is produced in California by refining the bitumen from the extensive sandstone and other deposits which are found in various parts of the State. The characteristics of both the crude and refined asphaltum from some of the more important deposits are shown by the following analysis:

ANALYSIS OF ASPHALTUM FROM BAKERSFIELD, CAL.

	Crude.	Refined.
Specific gravity	1.132	1.240
Softens at	180° F.	150° F.
Flows at	220° F.	180° F.
Inorganic matter	9.57 p. c.	9 77 p. c.
Bitumen soluble in CS_2	85.49 p. c.	90.16 p. c.
Bitumen soluble in ether	69.98 p. c.	86.45 p. c.
Percentage of total bitumen soluble in ether	81.85 p. c.	95.88 p. c.

ANALYSIS OF ASPHALTUM FROM ASPHALTO, CAL.

	Crude.	Refined
Moisture	6.51 p. c.	0.42 p. c.
Bitumen soluble in chloroform	84.79 p. c.	93.27 p. c.
Organic matter (not bitumen)	trace	0.54 p. c.
Inorganic matter consisting of infusorial earth with traces of iron	8.70 p. c.	5.77 p. c.
Petrolene soluble in acetone	67.50 p. c.	71.27 p. c.
Asphaltene insoluble in acetone	32.50 p. c.	28.73 p. c.
Combined sulphur (chemically held in the bitumen)	0.73 p. c.	

ANALYSIS OF ASPHALTUM FROM SANTA BARBARA CO., CAL.

	Crude.	Refined.
Specific gravity	1.250	
Organic non-bituminous matter	1.10 p. c.	
Inorganic matter consisting of finely divided quartz with oxide of iron and alumina	39.75 p. c.	
Bitumen soluble in CS_2	59.15 p. c.	
Bitumen soluble in petroleum naphtha (petrolene)		42.50 p. c.
Asphaltene		7.35 p. c.

ANALYSIS OF ASPHALTUM FROM KERN CO., CAL.

Bitumen soluble in CS_2	78.90 p. c.
Mineral substances—sand, clay, and silica	9.40 p. c.
Coky and volatile matter	4.53 p. c.
Water and loss	7.17 p. c.

ANALYSIS OF BITUMINOUS SANDSTONE FROM VENTURA CO., CAL.

Bitumen	24.00 p. c.
Silica	64.00 p. c.
Oxide of iron } Calcium carbonate }	12.00 p. c.

Cements for paving and other purposes are manufactured from the refined asphaltum described above by the admixture of *maltha*; the two substances are combined at a very low temperature, the heat being applied indirectly, and the mixing is performed mechanically; the degree of softness can be made to suit any requirement.

ASPHALT MASTIC.—In Europe mastic is made from a mixture of bituminous limestone and refined asphaltum (usually Trinidad). The bituminous limestone is reduced to powder and mixed with about 8 per cent of refined asphaltum, then melted and thoroughly mixed. The hot composition is run into moulds of various shapes, usually round or hexagonal, and of such dimensions

as will give a cake or block weighing about 56 pounds; these blocks usually have the name of the source or factory moulded on them.

The mastic is prepared for use by breaking the cakes into small pieces, and heating it with the addition of about 5 per cent of refined asphaltum. The mass is constantly stirred, and, when soft, sand and fine gravel are added and thoroughly incorporated by stirring for about two hours at a temperature of about 300° F., when it is ready for use.

Asphalt mastic is also prepared from bituminous sandstones and maltha or refined asphaltum, and from asphalt paving-cement. The principal use of mastic is for sidewalks and floors. In Europe it is called *asphalte coulé* in distinction from the compressed bituminous limestone, which is called *asphalte comprimé.*

ARTIFICIAL ASPHALT PAVEMENTS. — The pavements made from Trinidad, Bermudez, California, and similar asphaltums are composed of mechanical mixtures of asphaltic cement, sand, and stone-dust.

The asphaltic cement is prepared in the manner described on page 49. Its consistency should be such that at a temperature of from 70° to 80° F. it can be easily indented with the finger-nail, and on being heated to about 90° F. can be drawn out in strings and threads.

The sand should be equal in quality to that used for hydraulic cement mortar; it must be entirely free from clay, loam, and vegetable impurities; its grains should be angular and range from coarse to fine.

The stone-dust is used to aid in filling the voids in the sand and thus reduce the amount of cement. The amount used varies with the coarseness of the sand and the quality of the cement, and ranges from 5 to 15 per cent. (The voids in sand vary from .3 to .5 per cent.)

As to the quality of the stone-dust, that from any durable stone is equally suitable. Limestone-dust was originally used, and has never been entirely discarded.

The paving composition is prepared by heating the mixed sand and stone-dust and the asphalt cement separately to a temperature of about 300° F. The heated ingredients are measured into a pug-mill and thoroughly incorporated. When this is accomplished the mixture is ready for use. It is hauled to the street and spread with iron rakes to such depth as will give the required thickness when compacted (the finished thickness varies

between $1\frac{1}{4}$ and $2\frac{1}{2}$ inches). The reduction of thickness by compression is generally about 40 per cent.

The mixture is sometimes laid in two layers. The first is called the "binder"- or "cushion"- coat; it contains from 2 to 5 per cent more cement than the surface-coat; its thickness is usually $\frac{1}{2}$ inch. The object of the binder-course is to unite the surface mixture with the foundation, which it does through the larger percentage of cement that it contains, and which if put in the surface mixture would render it too soft.

The paving composition is compressed by means of rollers and tamping-irons, the latter being heated in a fire contained in an iron basket mounted on wheels. These irons are used for tamping such portions as are inaccessible to the roller, viz., gutters, and around man-hole heads, etc.

Two rollers are sometimes employed: one, weighing 5 to 6 tons and of narrow tread, is used to give the first compression; and the other, weighing about 10 tons and of broad tread, is used for finishing. The amount of rolling varies; the average is about one hour per thousand square yards of surface. After the primary compression natural hydraulic or any impalpable mineral matter is sprinkled over the surface to prevent the adhesion of the material to the roller and to give the surface a more pleasing appearance. When the asphalt is laid up to the curb the surface of the portion forming the gutter is painted with a coat of hot cement.

The concrete for the foundation is prepared in the manner described on page 224 *et seq.* The concrete must be thoroughly set and its surface dry before the asphalt is laid upon it; if not the water will be sucked up and converted into steam, with the result that coherence of the asphaltic mixture is prevented, and, although its surface may be smooth, the mass is really honeycombed, and as soon as the pavement is subjected to the action of traffic the voids or fissures formed by the steam appear on the surface, and the whole pavement is quickly broken up.

Although asphaltum is a bad conductor of heat, and the cement retains its plasticity for several hours, occasions may and do arise through which the composition before it is spread has cooled; its condition when this happens is analogous to hydraulic cement which has taken a "set," and the same rules which apply to hydraulic cement in this condition should be respected in regard to asphaltic cement.

The proportions of the ingredients in the paving mixture are

not constant, but vary with the climate of the place where the pavement is to be used, the character of the sand, and the amount and character of the traffic that will use the pavement. The range in the proportions is as follows:

Asphalt cement	12 to 15 per cent
Sand	70 to 83 " "
Stone-dust	5 to 15 " "

A cubic yard of the prepared material weighs about 4500 pounds and will lay the following amount of wearing-surface:

2½ inches thick	12 square yards
2 " "	18 " "
1½ " "	27 " "

One ton of refined asphaltum makes about 2300 pounds of asphalt cement, equal to about 3.4 cubic yards of surface material.

Broken-stone Pavements.

TELFORD PAVEMENT is constructed about as follows: The surface of the roadbed is graded uniformly and compressed by rolling. On this is laid a course of large irregular-shaped stones about 8 inches thick. The broadest surface is placed on the earth-bed, and the wedge-shaped spaces between the stones are then filled with smaller pieces and chips of stone. The projecting corners of the large stones are then broken off with hammers, and the course rolled or not with a steam-roller. On the surface of the large stones a layer of broken stone is spread, the binding added, sprinkled, and rolled; in some cases a second and third course of broken stone is added, sprinkled, and rolled in the same manner as the first. A surface-coat of screenings completes the work.

MACADAM PAVEMENT is constructed in the same manner as the Telford, omitting the lower course of large stone, the total depth of the broken stone varying from 4 to 12 inches in thickness.

INSPECTION OF TELFORD AND MACADAM.—In the construction of either Telford or Macadam pavement the points to be observed are: 1. The perfect consolidation of the earth-bed. 2. In Telford base the proper binding of the foundation-course. 3. Cleanliness of the stone; it must be free from clay and loam,

4. Size of the stone. A ring-gauge of the diameter of the largest stone should be provided, through which a stone should be frequently passed to test the size. This gauge is rarely furnished, the rule being used instead. Long flaky pieces, or "tailings," must be excluded; they will never compact, no matter how much they are rolled. 5. An excessive quantity of binding must not be used. The proportion should be about equal to the voids in the broken stone. By using a larger quantity than this the amount of rolling is lessened, but at the expense of durability. 6. The use of a large quantity of water must be avoided. A large quantity expedites the rolling, but softens the foundation. The water should be applied by a sprinkler, and not be thrown on in quantity from the plain nozzle of a hose. 7. The amount of rolling varies extremely with circumstances—the class of material, the amount of binding and water used, the gradient, and the pressure of steam maintained. The only guide for its proper amount is that it must be continued until the stones cease to creep in front or sink under the rolls, and the surface has become smooth and firm. The surface of a well-constructed broken-stone road should, after being rolled, look almost like an encaustic pavement.

The rolling should be done slowly, commencing at the sides and advancing to the centre.

VOIDS IN BROKEN STONE.—The proportion of voids in broken stone, gravel, and sand may be determined in either of the following ways: (1) Determine the specific gravity of the material and from that the weight of a unit of volume of the solid. Weigh a unit of volume of the loose material. The difference between the weights divided by the first gives the proportion of the voids. (2) Wet the loose material thoroughly, fill a vessel of known capacity with it, and then pour in all the water the vessel will contain. Measure the volume of water required and divide this by the volume of the vessel; the quotient represents the proportion of voids.

To ascertain the WEIGHT of a cubic yard of broken stone, multiply the weight of a cubic yard of the given stone by the proportion of voids (usually one-half); the result will be the weight of a cubic yard of the stone when broken.

The AREA covered by a cubic yard of ordinary broken stone is about 32 square yards of surface.

When the stone is rolled the primitive volume is reduced by about one-fourth,

To find the area covered by one cubic yard, divide 36 by the thickness of the layer in inches for unrolled stone; the quotient is the number of square yards that can be covered. When the stone is rolled divide 27 by the final thickness in inches; the quotient is the number of square yards.

Brick Pavements.

The qualities essential to a good paving-brick are the same as for any other paving material, viz., hardness, toughness, and ability to resist the disintegrating effects of water and frost. The required qualities are imparted to the brick by a process of annealing. The bricks are burned just to the point of fusion, then the heat gradually reduced until the kiln is cold. The clay employed in the manufacture of paving-brick must be rich in silica, free from lime, and able to withstand without fusing a red heat for a sufficient length of time to render the bricks hard, homogeneous, and impervious to water.

The characteristics of brick suitable for paving are:

1. Not to be acted upon by acids.
2. Not to absorb more than $\frac{1}{100}$ of its weight of water in 48 hours' immersion.
3. Not susceptible to polish.
4. Rough to the touch, resembling fine sandpaper.
5. To give a clear ringing sound when struck together.
6. When broken to show a compact, uniform, close-grained structure, free from air-holes and pebbles. Marked laminations are fatal defects.
7. Not to spall, chip, or scale when quickly struck on the edges.
8. Hard, but not brittle.

TESTS FOR PAVING-BRICK. — Paving-bricks are tested to ascertain

1. Resistance to crushing.
2. Resistance to cross-breaking.
3. Resistance to abrasion or impact.
4. Porosity or absorptive power.

The first test is conducted in a suitable testing-machine. The second is made by setting the brick edgewise on rounded knife-edges 7 inches apart, and loading it at the centre on a rounded knife-edge with weights until it breaks.

The breaking weight per square inch or the resistance to cross-breaking is deduced by the formula

$$R = \frac{3Wl}{2bd^2},$$

in which R = modulus of rupture;
W = breaking load;
l = distance between supports;
b = breadth;
d = depth or width.

The resistance to abrasion is usually made in a "rattler," such as is employed in foundries to clean small castings. In it are placed several bricks (usually 5), with a quantity (about 100 pounds) of cast-iron scrap in pieces weighing about half a pound each. The rattler is revolved at from 15 to 25 revolutions per minute for 30 minutes. The bricks are then weighed, replaced, and the operation repeated for another 30 minutes, when they are again weighed and the loss calculated.

THE ABSORPTION TEST is made by drying the brick and weighing it, then soaking it in water for a given number of hours (from 5 to 24) and weighing again. The difference in the dry and wet weights should be small. Any brick absorbing more than one per cent of its weight in 24 hours is open to suspicion as being liable to disintegration from frost.

A rough test for a well-burnt paving-brick is to let it drop flatwise from a height of 4 feet onto a second brick set edgewise. It should stand this test without breaking.

LAYING PAVING-BRICKS.—The foundations employed for bricks are sand, sand and gravel, broken stone, and cement concrete. The bricks are laid in a bed of sand spread upon the foundation, and screeded to a uniform depth, ranging from 1½ to 3 inches.

The bricks are usually laid on edge in straight courses across the street, with the length of the bricks at right angles to the axis of the street. Joints should be broken by a lap of at least 3 inches. None but whole bricks should be used, except in starting a course or making a closure. Before the closure is made each single course must be pressed as compactly together as possible with an iron bar applied to the curb-end of the row, and then keyed in place with a close-fitting brick. After 25 or 30 feet of the pavement is laid every part of it must be rammed

with a rammer weighing not less than 50 pounds, and the bricks which sink below the general level must be removed and replaced by a brick of greater depth. After the ramming and rectification the joint filling is applied. It is either sand, cement grout, or paving-pitch.

PROPERTIES OF PAVING-BRICKS.—Paving-bricks range in weight from 5½ to 7¼ pounds; in specific gravity, from 1.91 to 2.70; in resistance to crushing, from 7000 to 18,000 pounds per square inch; in resistance to cross-breaking, $R = 1400$ to 2000 pounds; in absorption, from 0.15 to 3 per cent in 24 hours. The dimensions vary according to locality and the requirements of the specifications. The "standard" bricks are $2\frac{1}{4} \times 4 \times 8$ inches, requiring 58 bricks to the square yard, and weigh 7 pounds each; "repressed," $2\frac{1}{2} \times 4 \times 8\frac{1}{2}$, requiring 61 to the square yard, and weigh 6¾ pounds each; "Metropolitan," $3 \times 4 \times 9$, requiring 45 to the square yard, and weigh 9½ pounds each.

Artificial-stone Pavements.

Pavements formed of artificial stone or concretes composed of hydraulic cement, crushed stone, sand, and gravel, with sometimes the addition of some indurating mineral substance, as baryta, litharge, etc., are extensively used for sidewalk and alley pavements; they are usually manufactured under a patent, either in place or in the form of blocks at a factory. Several varieties are in use, known by special names, as "kosmocrete," "granolithic," "monolithic," "ferrolithic," "metalithic," etc. The process of manufacture is practically the same for all kinds, the difference being in the indurating material employed.

The manner of laying is practically the same for all kinds. The area to be paved is excavated to a minimum depth of 8 inches and to such greater depths as the nature of the ground may require to secure a solid foundation. The surface of the ground so exposed is well compacted by ramming, and a layer of gravel, ashes, clinkers, or broken stone is spread and thoroughly consolidated by ramming; on this foundation the concrete wearing-surface is placed, rammed, and floated.

The principal precaution to be observed with good materials is that proper provision is made against the action of frost. This action is provided against by laying the concrete in blocks, forming rectangles, squares, or other forms having areas ranging from 6 to 30 square feet, strips of wood being employed to form moulds

in which the concrete is placed. After the concrete is set these strips are removed, leaving joints about half an inch in width between the blocks. Under some patents these joints are filled with cement, under others with tarred paper, etc.

Flagging.

The stones used for flagging are granite, limestone, and sandstone (Hudson River bluestone is a sandstone). The inspection will comprise the quality of the stone, the dimensions, especially the thickness and the dressing of the joints; the edges should be dressed true to the square for the whole thickness of the stone, and not left feather-edge, as is very common. The laying should be carefully done on a bed of sand, gravel, or cinders, and the joints filled with cement mortar.

Curbstones.

Curbstones are employed for the outer side of footways to sustain the pavement and form the gutter. The upper inside edge is set flush with the footwalk pavement, and the upper surface is cut to a bevel so that the water can flow over them into the gutter. The materials employed are granite, sandstone, bluestone, artificial stones, etc.

The inspection includes an examination of the quality, dimensions, cutting, and setting.

The setting requires to be carefully done, so that the stones shall stand to the true line and grade; the ramming and bedding must be faithfully performed or the stones will sink and turn slightly over. Curbstones carelessly set never present a pleasing appearance.

CHAPTER IV.

MISCELLANEOUS.

Weights and Measures.

The origin of English measures is the grain of corn. Thirty-two grains of wheat, dried and gathered from the middle of the ear, weighed what was called 1 pennyweight; 20 pennyweights were called 1 ounce, and 20 ounces 1 pound. Subsequently the pennyweight was divided into 24 grains.

Troy weight was afterwards introduced by William the Conqueror, from Troyes, in France; but it gave dissatisfaction, as the troy pound did not weigh as much as the pound then in use; consequently a mean weight was established, making 16 ounces equal to 1 pound, and called avoirdupois.

Three grains of barleycorn well dried, placed end to end, made an inch—the basis of length. The length of the arm of King Henry I. was made the length of the ulna, or ell, which answers to the modern yard.

The standard measure of length of both Great Britain and the United States is, in theory, that of a pendulum vibrating seconds at the level of the sea, in the latitude of London, in a vacuum, with Fahrenheit's thermometer at 62°. The length of such a pendulum is supposed to be divided into 39.1393 equal parts called inches, and 36 of these inches were adopted as the standard yard of both countries.

Troy Weight.

24 grains	= 1 pennyweight: dwt.
20 pennyweights	= 1 ounce = 480 grains.
12 ounces	= 1 pound = 240 dwt. = 5760 grains = 22.7944 cubic inches of distilled water, barometer 30 inches.

Avoirdupois or Commercial Weight.

27.34375 grains	= 1 drachm.
16 drachms	= 1 ounce = 437.5 grains.
16 ounces	= 1 pound = 256 drachms = 7000 grains = 27.7015 cubic inches of distilled water, barometer 30 inches.
28 pounds	= 1 quarter = 448 ounces.
4 quarters	= 1 cwt. = 112 pounds.
20 cwt.	= 1 ton = 80 quarters = 2240 pounds.

The ton of 2240 pounds, known as the long ton, is the standard used by the United States Government at the customhouses, but in commercial transactions the *short* ton of 2000 pounds is used unless otherwise specified.

Apothecaries' Weight.

20 grains	= 1 scruple.	8 drachms	= 1 ounce.
3 scruples	= 1 drachm.	12 ounces	= 1 pound.

The grain in each of the foregoing tables is the same.

An avoirdupois pound of pure water has the following volumes:

At 32° F.	= .016021 cubic feet	or 27.684 cubic inches.
39.1° "	= .016019 " "	" 27.680 " "
62° "	= .016037 " "	" 27.712 " "
212° "	= .016770 " "	" 28.978 " "

Lineal Measure.

12 inches	= 1 foot.
3 feet	= 1 yard.
5½ yards	= 1 rod or perch = 16½ feet.
40 rods	= 1 furlong = 220 yards = 660 feet.
8 furlongs	= 1 mile = 320 rods = 1760 yards = 5280 feet.

The British measure of length is about $\frac{1}{14}$ of an inch in 100 feet, or 3⅝ inches in a mile, shorter than that of the United States.

To convert British linear dimensions into American multiply by 1.000058, and American into British multiply by .999942.

Square Measure.

144 square inches	= 1 square foot.
9 square feet	= 1 square yard.
30¼ square yards	= 1 square rod.
40 square rods	= 1 rood.
4 roods	= 1 acre = 43560 square feet.

A square acre is 208.71 feet on each side.

A circular acre is 235.504 feet in diameter.

A half acre is = to 147.581 feet on each side.

A quarter acre is = to 104.355 feet on each side.

100 square feet = 1 square.

Cubic or Solid Measure.

1728 cubic inches	= 1 cubic foot.	
27 cubic feet	= 1 cubic yard.	
A perch of stone	= 24.75 cubic feet	= 16′ 6″ × 1′ 6″ × 1′.
A cord of stone	= 99 cubic feet	= 4 perches.
A cord of wood	= 128 cubic feet	= 4′ × 4′ × 8′.
A ton of bituminous coal	= 44 to 48 cubic feet.	
A ton of anthracite "	= 41 to 43 " "	

1 gallon water = 231 cubic inches.
1 cubic foot = 7.48 gallons.

Liquid Measure.

4 gills	= 1 pint	= 28.875	cubic inches.
2 pints	= 1 quart	= 57.750	" "
4 quarts	= 1 gallon	= 231.0	" "

A cylinder 3½ inches in diameter and 6 inches high will hold almost exactly 1 quart, and one 7 inches in diameter and 6 inches high will hold very nearly one gallon.

A gallon of water weighs 8.338 pounds avoirdupois.

Dry Measure.

2 pints	= 1 quart	= 1 16365	liquid quarts.
4 quarts	= 1 gallon	= 268.8025	cubic inches.
2 gallons	= 1 peck	= 537.6050	" "
4 pecks	= 1 struck bushel	= 2150.42	" "

A struck bushel = 1.24445 cubic feet.

A cubic foot = .80356 of a struck bushel.

A flour barrel contains 3 struck bushels.

A heaped bushel = 1¼ "struck" bushels = 1.555 cubic feet. When heaped the cone must be at least 6 inches high. The bushel measure is a cylindrical vessel 18½ inches in diameter and 8 inches deep.

MISCELLANEOUS MEASURES.

12 units	= 1 dozen.
12 dozen	= 1 gross.
12 gross	= 1 great gross.
20 units	= 1 score.
24 sheets of paper	= 1 quire.
20 quires	= 1 ream.
2 reams	= 1 bundle.
5 bundles	= 1 bale.
25 lbs. powder	= 1 keg.
14 lbs.	= 1 stone.
100 lbs.	= 1 quintal.
1 chaldron	= 36 bushels or 57.244 cubic feet.
1 ton displacement in salt water	= 35 cubic feet.
1 fathom	= 6 feet.
1 cable length	= 120 fathoms.

THE METRIC STANDARDS OF WEIGHTS AND MEASURES.

The metric unit of length is the metre = 39.37 inches.

The metric unit of weight is the gram = 15.432 grains.

The following prefixes are used for subdivisions and multiples: Milli = $\frac{1}{1000}$, Centi = $\frac{1}{100}$, Deci = $\frac{1}{10}$, Deca = 10, Hecto = 100, Kilo = 1000, Myria = 10,000.

MEASURES OF LENGTH.

1	metre	= 39.37 in., or 3.28083 ft., or 1.09361 yd.
.3048	"	= 1 foot.
1	centimetre	= .3937 inch.
2.54	centimetres	= 1 inch.
1	millimetre	= .03937 inch, or $\frac{1}{25}$ inch nearly.
25.4	millimetres	= 1 inch.
1	kilometre	= 3280.83 ft., or 1093.61 yds., or 0.62137 mill.

MEASURES OF SURFACE.

1 square metre	= 10.764 square feet or 1.196 sq. yd.
.836 " "	= 1 sq. yd.
.0929 " "	= 1 sq. ft.
1 " centimetre	= .155 sq. in.
6.452 " centimetres	= 1 sq. in.
1 square millimetre	= .00155 sq. in.

645.2	square millimetres	= 1 sq. in.		
1	centiare	= 1 sq. metre	=	10.764 sq. ft.
1	are	= 1 sq. decametre	=	1076.4 " "
1	hectare	= 100 ares	=	107641 " "
			=	2.4711 acres.
1	square kilometre	= .386109 sq. mile	=	247.11 "
1	square myriametre	= 38.6109 " "		

MEASURES OF VOLUME.

1	cubic metre	= 35.314 cu. ft.	=	1.308 cu. yd.
.7645	" "	= 1 cu. yd.		
.02832	" "	= 1 cu. ft.		
1	" decimetre	= 61.023 cu. in.	=	.0353 cu. ft.
28.32	" "	= 1 cu. ft.		
1	" centimetre	= .061 cu. in.		
16.387	" "	= 1 cu. in.		
1	" "	= 1 millimetre	=	.061 cu. in.
1 centilitre		= .610 cu. in.		
1 decilitre		= 6.102 " "		
1 litre=1 cubic decimetre		= 61.023 " "	=	1.05671 quarts.
1 hectolitre or decistere		= 3.314 cu. ft.	=	2.8375 bushels.
1 stere, kilolitre, or cubic metre		= 1.308 cu. yd.	=	28.37 bush.

MEASURES OF CAPACITY.

1	litre	= 1 cubic decimetre	= 61.023 cu. in.
			= .03531 cu. ft.
			= .2642 gall.
			= 2.202 lbs. of water at 62° F.

28.317 litres	= 1 cu. ft.	
4.543 "	= 1 gallon	(British).
3.785 "	= 1 "	(American).

MEASURES OF WEIGHT.

1	gramme	= 15.432 grains.
.0648	"	= 1 grain.
28.35	"	= 1 ounce avoirdupois.
1	kilogramme	= 2.2046 lbs. "
.4536	"	= 1 lb. "
1 tonne or metric ton 1000 kilogrammes		= 2204.6 lbs. or .9842 ton of 2240 lbs.
1016	"	= 1 ton of 2240 lbs.

Table 79.

INCHES AND THEIR EQUIVALENT DECIMAL VALUES IN PARTS OF A FOOT.

DECIMAL EQUIVALENTS FOR FRACTIONS OF AN INCH.

1/64	.015625	¼	2500	½	.5000	¾	.7500
1/32	.03125	9/32	28125	17/32	.53125	25/32	.78125
1/16	.0625	5/16	.3125	9/16	5625	13/16	.8125
3/32	09375	11/32	34375	19/32	59375	27/32	.84375
⅛	.1250	⅜	3750	⅝	.6250	⅞	8750
5/32	.1563	13/32	40625	21/32	.65625	29/32	.90625
3/16	.1875	7/16	4375	11/16	6875	15/16	.9375
7/32	.2187	15/32	.46875	23/32	.71875	31/32	.96875

Specific Gravity.

By specific gravity is meant the weight of a substance compared with the weight of water, taking equal volumes of each. Water is adopted as the standard of gravity; as a cubic foot of it at 62° F weighs 997.68 ounces avoirdupois, its weight is taken as the unit or approximately 1000. A cubic foot of cast iron weighs about 7½ times as much as a cubic foot of water, but a cubic foot of cork weighs less than one-fourth as much as a cubic foot of water, and so the specific gravity of cast iron is set down as 7.5, and that of cork as 0.24.

To ascertain the specific gravity of a solid body heavier than water, weigh it both in and out of water, and note the difference; then as weight lost in water is to whole weight so is 1000 to specific gravity of the body, or

$$\frac{W \times 1000}{W - w} = G,$$

W and w representing weights out of and in water and G specific gravity.

If the substance be lighter than water sink it by means of a heavier substance and deduct weight of the heavier substance.

Weight of a cubic foot in pounds = specific gravity × 62.425, or specific gravity × 1000 and divided by 16 = weight in pounds.

TABLE 80.

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Acacia-wood	.750	46.5
Acetone	.792	49.4
Acid, acetic, monohydrated	1.068	66.37
" " greatest density	1.079	67.3
" arsenic	3.391	212 0
" arsenious	3.782	233.0
" benzoic	.667	41.7
" boracic, crystallized	1.479	92.44
" " fused	1.803	112.7
" carbonic	.00197	.123
" chlorohydric, concentrated liquid	1.208	75.5
" citric	1.034	64.67
" cyanohydric	.696	43.5
" formic	1.116	70.0
" fluoric	1.060	66.25
" hydrochloric (muriatic)	1.200	75.0
" hyponitric	1.451	9.7
" hyposulphuric, most concentrated	1.347	84 2
" molybdic	3.460	216.25
" nitric, fuming	1.451	90.7
" " of commerce	1.220	76.25
" " tetrahydrated	1.420	88.75
" oleic	.898	56.125
" phosphoric, liquid	1.558	97.37
" " solid	2.800	175.0
" silicic, quartz	2.653	165.6
" " agate	2.615	168.1
" " opal, hydrated silica	2.250	140.6
" sulphuric, most concentrated	1.841	115.0
" sulphurous	2.210	138.1
" tannic	....	....
" tartaric	....	....
" telluric	....	....
" tellurous	....	....
Agate	2.615	163.4
Air at 60° F., barometer 30″	.001205	.075
Alabaster	2.700	168.75
Alcohol, absolute, 60°	.792	49.5
" greatest density	.927	58.0
" of commerce	.834	52 1
" proof spirit	.916	57.25
Aldehyde	.790	49.4
Alder-wood	.800	50.0
Alum	1.714	107.1
Alumina { corundum, sapphire, ruby }	4.160	260.0
" emery	3.900	243.75
Aluminate of magnesia (spinel)	3.700	231.25
" " zinc	4.700	293.75
Aluminium	2.600	162.5
Amber	1.078	67.37
Ambergris	.866	54.1
Amethyst, common	2.750	172.0
" oriental	3.391	212.0
Amanthus, 313 to 1.000	.657	41.1
Ammonia, aqueous	.857	53.6
Antimony, cast, 6.67 to 6.75	6.710	419.37

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Antimony, native	6.670	417.9
Apple-wood	.793	49.0
Aqua fortis, double	1.300	81.25
" " single	1.200	75.00
Arragonite	2.900	181.25
Arsenic	5.673	354.6
Asbestos, starry	3.073	192.1
Ash, perfectly dry, average	.752	47.0
" American, white, dry	.610	38.15
Asphaltum, .905 to 1.65	1.277	80.0
Azure, stone	2.850	178.15
Bamboo	.400	25.0
Barytes, sulphate of, 4 to 4.558	4.279	267.3
" carbonate of, 4.1 to 4.6	4.350	272.0
Barium	.470	29.4
Basalt, 2.421 to 3.000	2.710	169.4
Bathstone (oölite)	2.100	131.25
Baytree-wood	.822	51.4
Beech-wood, .852 to .690	.771	48.2
" " perfectly dry	.624	39.0
Beer	1.034	64.62
Beeswax	.965	60.31
Beryl, oriental	3.594	223.4
" occidental	2.723	170.2
Bichloride of mercury	5.420	338.75
Bismuth	9.822	614.0
Bisulphide of mercury	8.124	507.75
" " tin	4.415	276.0
Birch	.567	354.4
Bitumen, liquid	.848	53.00
Blood, human	1.053	65 875
" crassamentum of	1.245	77.8
Borate of magnesia (boracite)	2.500	156.25
Brandy	.924	57.75
Brass (copper and zinc), cast, average	8.100	506.0
" copper 67, zinc 33 parts	7.820	488.75
" " 84, tin 16	8.832	552.0
" rolled or plate	8.380	524.0
" wire	8.214	513.4
Brick, pressed	2.400	150.0
" common, 1.367 to 1.40	1.633	102.1
" fire	2.201	137.6
" work in cement	1.800	112.5
" " in mortar 1.6 to 2	1.800	112.5
" soft	1.600	100.0
Bromine	3.000	187.5
Bronze, copper 8 parts, tin 1	8.500	531.25
Bullet-wood	.928	58.0
Butter	.942	58.875
Butternut-wood	.376	23.5
Cadmium	8.690	543.7
Calcite, transparent, 2.52 to 2.73	2.620	163.75
Calcium	1.580	92.5
Campeachy wood	.913	57.0
Camphor	.998	62.4
Caoutchouc (india-rubber)	.903	56.4

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Carbon, diamond	3.530	220 6
" graphite	3.500	218.75
Carbonate of baryta	4.300	268.7
" " iron (iron spar)	3.850	240 6
" " lead (white lead)	6.730	420.6
" " lime (arragonite)	2.946	184.1
" " " (Iceland spar)	2.723	170 2
" " magnesia (giobertite)	2.880	180.0
" " manganese	3.550	222.0
" " strontia	3.650	228.1
Carnelian, speckled	2.613	163.3
Cedar, wild	.596	37.25
" Palestine	.613	38.3
" Indian	1.315	82.157
Cement, Am. hydraulic Rosendale, loose	....	60.0
" " " well shaken	....	70 0
" " " thoroughly shaken	....	80.0
" a struck bushel loose 75 lbs.	....	....
" " " well shaken 88 lbs.	....	....
" " " packed for sale 100 lbs.	....	....
" 1 barrel contains 3 struck bushels, or 3¾ cu. ft. packed.	....	....
" Portland, about 110 lbs. bushel, average	1 300	81.25
" Roman, " " " " "	1.560	97 25
Chalcedony, common, 2.6 to 2.65	2.625	164.1
Chalk, 2.252 to 2.657	2.454	153.4
Charcoal of pine	.441	27 562
" fresh burned	.380	23.75
" of oak	1.573	98.312
" of soft wood	.280	17 50
" triturated	1.380	86.25
Cherry	.715	44.7
" well seasoned	.672	42.0
Chestnut, perfectly dry	.660	41.25
Chromium	5.900	368.75
Chloride of ammonium (sal ammonia)	1.520	95.0
" " barium	3.900	231.5
" " calcium	3 200	200.0
" " silver	5.548	346.75
" " sodium	2.100	131.25
" " potassium	1.836	114.75
Chromate of lead	6.600	412.5
" " potash	2.700	168.7
Chrysolite, 2.782 to 3.400	3.091	193.2
Cider	1.080	67 5
Cinnabar	8.098	506.1
" from Almaden	6 920	432 5
Citron-wood	.726	45.4
Clay, dry potter's, 1.8 to 2.1	1.900	119.0
" " in loose lumps	....	63.0
" with gravel	2.480	155.0
Coal, anthracite, 1 436 to 1.64	1.538	96.1
" a solid yard makes 1¾ yds when broken for use	....	....
" cannel, 1.238 to 1.318	1.278	80.0
" caking	1.277	79.8
" bituminous, 1.2 to 1.5	1.350	84.4
" broken, loose	....	47-52
" a heaped bushel 70 to 78 lbs.	....	....
" a ton occupies from 43 to 48 cu. ft.	....	....
Cobalt	8.600	537.5

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Cobalt, cast	7.812	488.25
Cocoa-wood	1.040	65.0
Coke	1.000	62.5
" loose, of good coal		23-32
" National of Va	.746	46.62
" a heaped bushel 35 to 42 lbs		
" a ton 80 to 97 cu. ft		
Columbium	6.000	375.0
Concrete, mean	2 000	125.0
Copper, cast	8.788	549.25
" rolled	8.950	560.0
" wire	8.880	555.0
Copal	1.045	65.3
Coral, red	2.700	168.75
" white	2.550	160 0
Cork	.240	15.0
Cornelian	2.618	163.3
Corundum	3.710	23[illegible].0
Crab tree	.765	47.81
Cypress-tree	.644	40.25
" " well seasoned	.441	27.6
Deal-wood, Christiania	.689	43.0
Deutoxide of mercury	6.320	395.0
Deutoxide of mercury	11.000	687.5
" " copper	6.130	383.12
" " tin	6.700	418.75
Diamond, oriental, colorless	3.521	220.1
" " colored, average	3.536	221.0
" Brazilian	3.444	215.25
" " colored	3.550	222.0
Dogwood	.756	47.25
Dolomite, 2.54 to 2.83	2.685	168.0
Dragon's blood (a resin)	1.204	75.25
Earth, dry common loam, loose	1.280	72-80
" " " soil	2.194	137⅛
" loose dry	1.500	93.75
" " slightly moist		70-76
" shaken, more "		75-90
" fluid mud		104-112
" moist sand	2.050	128⅛
" mould, fresh	2.050	128⅛
" rammed	1.600	100.0
" rough sand	1.920	120.0
" with gravel	2.020	126¼
Ebony, American	1.381	86⅛
" Indian	1.209	75⅛
Egg	1.090	68.0
Elker-wood	.695	43.4
Elm, perfectly dry	.570	35.6
"	.671	42.0
Emerald	2.680	167.5
Emery	4.000	250.0
Ether, acetic	0.868	54.1
" chlorohydric	.874	54.6
" muriatic	.729	45.6
" nitric	.908	56.75
" sulphuric	.715	44.7

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. *(Continued.)*

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Fat of beef	.923	57.68
" " hogs	.936	58.5
" " mutton	.923	57.68
Feldspar, 2.438 to 2.700	2.569	160.6
Filbert-wood	.600	37.5
Fir, Norway	.512	32.0
Firestone	1.800	112.0
Flint, black	2.582	161.37
" white	2.504	156.5
Fluoride of calcium (fluor spar)	3.200	200.0
Fluorine	1.320	82.5
Fusel oil	.808	50.5
Gamboge	1.222	76.5
Garnet, precious, 4 to 4.23	4.115	257.2
" common, 3.576 to 4	3.288	205.5
Glass, 2.50 to 3.45	2.975	186.0
" bottle	2.732	170.75
" common window, crown	2.520	157.5
" thick flooring	2.530	158.1
" green	2.642	165.1
" flint, 2.76 to 3.00	2.880	180.0
" optical	3.450	215.6
" white	2.892	180.75
Gneiss, common, 2.62 to 2.76	2.690	168.0
" in loose piles	....	96.0
" hornblendic	2.80	175.0
Granite, Egyptian red	2.654	165.9
" Patapsco	2.640	165.0
" Old Dominion, Va.	2.630	164.4
" Quincy	2.652	165.75
" Scotch	2.625	164.06
" Susquehanna, Pt. Deposit	2.704	169.00
Gravel, about equal to sand	1.749	109.31
Greenstone (trap), 2.8 to 3.2	3.000	187.0
" in loose piles	....	107.0
Grindstone	2.143	133.94
Gold, cast pure, 24 carat	19.258	1204.0
" native pure	19.320	1206.0
" hammered pure, 19.4 to 19.6	19.500	1217.0
" 22 carat	17.486	1093.0
" 20 "	15.709	982.0
Gum Arabic	1.452	90.75
Gum-tree, blue	.843	52.69
" " water	1.000	62.5
Gunpowder, loose	.900	56.25
" shaken	1.000	62.5
" solid $\left\{\begin{matrix}1.550\\1.800\end{matrix}\right\}$	1.675	104.7
Gutta-percha	.980	61.1
Gypsum (plaster of Paris), average	2.305	144.0
" in lumps	....	82.0
" ground, loose (struck bushel 70 lbs.)	....	56.0
" " well shaken 80 lbs	....	64.0
" " thoroughly shaken 90 lbs	....	72.0
Hackmatack-wood	.592	37.0
Hazel-wood	.860	53.75

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. *(Continued.)*

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Hawthorn-wood	.910	56.87
Heliotrope (bloodstone) {2.629 / 2.700}	2.664	166.5
Hemlock	.368	23.0
Hickory, pignut	.792	49.5
" shell-bark	.690	43.12
" red	.838	52.375
Holly	.760	47.5
Hone, white	2.876	179.75
Honey	1.450	90.62
Honeystone or mellite	1.620	101.25
Horn	1.689	105.56
Hornbeam-wood	.760	47.0
Hornblende	3.540	221.25
" black, 3.1 to 3.4	3.250	203.0
Hornstone, 2.533 to 2.810	2.671	167.0
Hyacinth, 4 to 4.78	4.390	273.1
Hydrogen gas	.000089	.0056
Ice at 32° F	.920	57.5
India-rubber	.903	56.437
Indigo	1.009	63.06
Iodide of potassium	3.000	187.5
" " silver	5.614	350.9
" " lead	6.100	381.25
Iodine	4.948	309.25
Iridium, cast by electric battery	18.680	1167.5
" hammered	23.000	1437.5
Iron, cast, 6.9 to 7.4	7.150	446.0
" at 450 lbs. to the foot, 8601.6 cu. in. will make a ton.	....	....
" wrought, 7.6 to 7.9	7.770	485.
" magnetic oxide	5.400	337.5
" cast, gun-metal	7.308	456.7
" hot-blast	7.065	441.6
" cold-blast	7.218	451.1
" wire	7.774	486.0
" rolled plates	7.704	481.15
" large rolled bars	7.690	480.0
Ironstone, 3.28 to 3.57	3.475	217.2
Ironwood	1.150	71.0
Isinglass	1.111	69.437
Ivory	1.825	114.062
Jackwood	.670	42.0
Jasmine	.770	48.125
Jasper, 2.358 to 2.816	2.587	161.7
Jet	1.300	81.25
Juniper	.566	35.37
Lancewood	.720	45.0
Larch-wood, 5.44 to 5.60	.552	34.5
Lard	.947	59.2
Lead, cast	11.352	709.5
" rolled	11.388	712.0
Lemon-tree	.703	43.94
Lignum-vitæ	1.333	83.31

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Lime-wood	.804	50.25
Lime, ordinary quick	.843	52.7
" hydraulic	2.745	171.5
" ground, loose, struck bushel 71 lbs	....	57.0
" " well shaken 80 lbs	....	64.0
" " thoroughly shaken 93¾ lbs	....	75.0
Limestones and marbles, 2.85 to 2.65	2.75	172.0
Limestones and marbles, one cu. yd. solid makes about 1.9 yds. loose, or 1¾ yds. piled when .571 is solid and .429 voids.	....	....
Linden-wood	.604	37.74
Lithium	.590	45.5
Locust-wood	.728	45.5
Logwood	.913	57.06
Magnesia, carbonate of	2.400	150.0
" native hydrate of	2.330	145.6
Magnetic oxide of iron	5.400	337.5
Mahogany, .72 to 1.063	.892	55.75
" Honduras	.560	35.0
" Spanish	.852	53.25
Malachite, compact	3.790	237.0
Manganese	8.000	500.0
Maple-wood	.750	46.87
" bird's-eye	.576	36.0
Marble, Adelaide	2.715	169.68
" African	2.708	169.25
" Biscayan, black	2.695	168.43
" Carrara	2.716	169.75
" common	2.689	167.87
" Egyptian	2.668	166.75
" French	2.649	165.56
" Italian, white	2.708	169.25
" Parian	2.838	177.37
" Vermont, white	2.650	165.57
Marl, mean	1.750	109.37
Masonry, of granite or limestone	....	165.0
" " well-scabbled rubble, 1/5 mortar	....	154.0
" " granite, dry rubble	....	138.0
" roughly scabbled rubble, ¼ to ⅙ mortar	....	150.0
" " " dry	....	125.0
Masonry, at 155 lbs. per cu. ft., a cu. yd. weighs 1.868 tons, and 14.45 cu. ft. = 1 ton.	....	....
Masonry of sandstone about ⅛ less than the above.	....	....
" " brickwork, pressed, fine joints	....	140.0
" " " medium	....	125.0
" " " coarse, soft bricks	....	100.0
Masonry, at 125 lbs. per cu. ft., a cu. yd. weighs 1507 tons, and 17.92 cu. ft. = 1 ton.	....	....
Mastic	1.074	67.125
" wood	.849	53.06
Melanite or black garnet	3.750	234.4
Mercaptan	.804	50.25
Mercury at 0° C. or 32° F	13.596	849.9
" " − 40° F	15.632	977.0
" " + 60° F	13.580	848.75
" " 112° F	13.370	835.6
Mica, 2.75 to 3.1	2.930	183.0
Millstone	2.484	155.25

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Milk	1.030	64.4
Mineral pitch or asphaltum, .905 to 1.650	1.277	80.0
" tallow	.770	48.1
Molybdenum	8.600	537.5
Molybdate of lead	6.700	418.75
Mortar, hardened, 1.4 to 1.9	1.650	103.0
Mud, dry close	......	80-110
" wet, moderately pressed	......	110-130
" " fluid	......	104-120
Mulberry-wood	.561	35.06
" Spanish	.897	56.06
Myrrh	1.360	85.0
Naphtha	.848	52.9
Nickel	8.666	541.6
" cast	8.279	517.3
Nitrate of baryta	3.185	199.1
" " lead	4.400	277.5
" " potash	1.930	120.6
" " strontia	2.890	180.6
Nitre	1.900	118.75
Nitrogen (about 1/35 lighter than air)	......	......
Oak, African	.823	51.437
" Canadian	.872	54.5
" Dantzic	.759	47.43
" English	.932	58.25
" green	1.146	71.625
" heart (60 years old)	1.170	73.125
" live, green	1.260	78.75
" " seasoned	1.068	66.75
" white, dry	.860	53.75
" red, black, etc	......	40.75
Obsidian	2.359	128.7
Oil of amber	.868	54.25
" " aniseseed	.986	61.625
" " sweet almonds	.932	58.25
" " bitter almonds	1.043	65.2
" " carraway-seed	.904	56.5
" " cinnamon	1.010	63.1
" " citron	.847	53.0
" " cloves	1.036	64.7
" " codfish	.923	57.6
" " cotton-seed	......	......
" " cumin	.969	60.6
" " hemp-seed	.926	57.9
" " lavender	.894	56.0
" " linseed	.940	58.75
" " naphtha	.848	53.0
" " olive	.915	57.18
" " palm	.969	60.56
" " petroleum	.878	54.875
" " poppy-seed	.939	58.7
" " rape-seed	.914	57.12
" " sunflower	.926	57.875
" " spirea	1.173	73.3
" " turpentine	.870	54.37
" " whale	.923	57.68

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Oil of wormwood	.907	56.7
Oleflant gas	.00127	.079
Olive-wood	.923	87.6
Oölites or roestones, 1.9 to 2.5	2.200	137.0
Opal, precious	2.114	132.1
" common	2.040	127.5
Opium	1.336	83.5
Orange-wood	.705	44.06
Orpiment, 3.048 to 3.5	3.274	204.6
Osmium	10.000	625.0
Oyster-shell	2.092	130.75
Oxide of bismuth	8.968	560.5
" " silver	7.250	453.1
" " zinc	5.600	350.0
Oxygen gas (1/10 heavier than air)	.00143	.089
Palladium	11.300	706.2
" rolled	11.800	737.5
Paving-stones	2.416	151.0
Pearl-wood	.661	41.31
Pearl, oriental, 2.51 to 2.75	2.630	164.4
Pearlstone	2.340	146-2
Peat, dry unpressed	....	20-30
Peroxide of iron	5.225	326.6
" " lead	9.200	575.0
" " manganese	4.480	280.0
" " titanium (rutile)	4.250	265.6
Persimmon-wood	.710	44.375
Peruvian bark	.784	49.0
Petroleum	.878	54.875
Phosphorus	1.770	110.60
Pine, Dantzic	.649	40.0
" Memel	.550	34.3
" Riga	.466	29.0
" white, perfectly dry	.400	25.0
" " 1000 ft. b. m. weighs .930 ton.	....	....
" yellow Northern, .48 to .62	.550	34.3
" 1000 ft. b. m. weighs 1.276 ton.	....	....
" yellow Southern, .64 to .80	.720	45.0
" " " heart, unseasoned	1.040	65.0
" pitch	1.150	71.7
Pitch	1.150	71.9
Pitchstone, 1.92 to 2.72	2.345	146.6
Plaster of Paris	1.176	73.5
Platinum	21.530	1342.0
" wire	21.042	1315.1
" rolled	22.060	1379.0
" in grains, native	17.500	1094.0
" forged	20.336	1271.0
Plum-wood	.785	49.06
Plumbago or graphite	2.200	137.5
Pomegranate	1.351	84.62
Poon-wood	.580	36.25
Poplar	.383	23.9
" white	.529	33.06
Porcelain, China	2.300	143.75
" Sevres	2.145	134.1
Porphyry, red	2.765	172.8
" Seltzer	1.003	62.7

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Potassium at 59° F	.865	54.1
Powder, slightly shaken	1.000	62.5
Proof spirit	.916	56.0
Protoxide of antimony	5.778	361.0
" " copper	5.300	331.2
" " lead, cast	9.500	593.7
Protochloride of mercury	7.140	446.0
Protoiodide of mercury	7.750	484.4
Protosulphide of tin	5.267	329.2
" " manganese	3.950	247.0
" " copper	5.690	355.6
Pumice-stone, .792 to .914	.883	55.2
Quartz, common pure	2.650	165.0
" finely pulverized, loose	....	90.0
" " " well shaken	....	105.0
" " " packed	....	112.0
" quarried loose, 1 part solid makes 1⅙ loose.	....	....
Quince-wood	.705	44.06
Realgar, 3.225 to 3.38	3.278	204.7
Red lead	8.940	558.7
Red oxide of manganese	4.722	295.1
Resin or rosin	1.089	68.1
Rhodium	10.650	665.6
Rock crystal	2 785	171.0
Rosewood	.728	45.5
Rotten stone	1.981	123.8
Ruby	4.040	252.5
Ruthenium	8.600	537.5
Salt	2.070	129.4
Saltpetre	2.090	130.62
Sand, pure quartz, dry and loose	1.650	90-106
" struck bushel 112 to 133 lbs.		
" average 98 lbs. per cubic foot.	....	....
Sand, a struck bush. = 122½ lbs., and 18.29 bush. = 1 ton. A cu. yd. = 1.181 tons, and 22.86 ft. = 1 ton.	....	....
Sand, well shaken, struck bushel 123-147 lbs	....	99–117
" " packed	....	101-119
" perfectly wet, drained off	....	120–140
Sandstones, for building, dry, 2.10–2.73	2.410	150.0
" piled, 1 measure solid = 1¾	....	86.0
Sapphire	3.994	237.1
" oriental	4.100	256.2
Sardonyx	2.615	163.4
Sassafras-wood	.482	30.122
Satinwood	.885	55.315
Scammony of Smyrna	1.274	79.6
Schorl	3.170	198.1
Sea-water	1.026	64.1
Selenium	4.400	275.0
Selenite of lead	7.690	480.6
Serpentine, 2.264 to 3.00	2.634	164.6
Sesquioxide of manganese	4.810	306.2
Shale, red or black	2.600	162.5
Shingle (pebbles and sand)	1.420	88.7

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Silicate of zirconia	....	....
Silver, pure cast	10.474	654.6
" hammered	10.511	686.9
" glance, 5.2 to 7.2	6 250	390.6
Slate, 2.672 to 2.90	2.791	178.2
" purple	2.784	174.0
" drawing	2.110	132.0
Smalt	2.440	152.0
Snow, freshly fallen	....	5-12
" compacted by rain	....	15-20
Soapstone or steatite, 2.65 to 2.80	2.730	170.0
Soap	1.071	66.9
Sodium at 59° F	.972	60.75
Spar, fluor, 3.094 to 3.791	3.442	215.1
" feld	2.700	168.75
" calc, 2.62 to 2.837	2.729	170.6
Spelter or zinc, 6.8 to 7.2	7.000	437.5
Spermaceti	.943	58.937
Spruce	.500	31.25
Stalactite, 2.323 to 2.546	2.434	152.1
Starch	.950	59.37
Steam	.0088	.055
Steel, 7.8 to 7.9	7.850	490.0
" plates	7.806	488.0
" soft	7.838	489.6
" tempered and hardened	7.818	488.6
" wire	7.847	490.4
Stone, Bath, Eng	1.961	122.56
" Blue Hill	2.640	165.0
" Bluestone (basalt)	2.625	164.0
" Breakneck, N. Y	2.704	169.0
" Bristol, Eng	2.510	156.8
" Caen, Normandy	2.076	129.75
" common	2.520	157.5
" Craigleth, Eng	2.316	144.75
" grind	2.142	134 0
" Kentish rag	2.651	165.6
" Kips Bay, N. Y	2.759	172.0
" Norfolk, Parliament House	2.304	144.0
" Portland, Eng	2.368	148.0
" rotten	1.981	123.8
" sandstone (mean)	2.400	150.0
" Sydney	2.237	139.8
" Staten Island, N. Y	2.976	186.0
" Sullivan Co	2.688	168.0
Strontium	2.540	158.7
Sugar	1.606	100.4
Sulphate of baryta (heavy spar)	4.700	293.7
" " strontia (celestine)	3.950	247.0
" " lead	6.300	393.7
" " silver	5.340	333.7
" " lime (anhydrite)	2.900	181.2
" " " (gypsum)	2.305	144.0
" " potash	2.400	150.0
" " soda, anhydrous	2.630	164.4
Sulphide of antimony	4.334	270.9
" " bismuth	6.540	408.7
" " carbon	1.263	789.4
" " lead (galena)	7.580	473.7
" " molybdenum	4.600	287.5
" " silver	7.200	450.0

SPECIFIC GRAVITY AND WEIGHT OF MATERIALS. (*Continued.*)

	Specific Gravity.	Weight of a Cubic Foot in Pounds.
Sulphide of zinc (blende)	4.160	260.0
Sulphur, native	2.086	180.4
" fused	1.990	124.4
Sycamore-wood	.623	39.0
Talc, mean	2.800	175.0
" black	2.900	181.25
Tallow	.940	58.6
Tamarack-tree	.383	23.93
Tar	1.000	62.25
Teak (African oak) 6.57 to 7.45	.701	43.8
Tellurium	6.110	382.0
Thalium	11.850	740.6
Tile	1.815	113.4
Tin, Cornish hammered	7.390	462.0
" " pure	7.291	455.7
Topaz, oriental	4.011	250.7
Tourmaline	3.210	200.6
Trap	2.720	170.0
Tungsten	17.600	1100.0
Turf or peat, dry and unpressed	... .	20–30
Turquoise, 2.50 to 3.00	2.750	172.0
Ultramarine	2.360	147.5
Uranium	18.230	1140.8
Vine-wood	1.327	83.0
Vinegar, 1.013 to 1.080	1.047	65.5
Walnut-wood	.671	41.937
" " black	.500	31.25
Water, pure rain or distilled, at 32° F	....	62.37
" " " " " " 60° F	1.000	62.331
" sea	1.026	64.1
" Dead Sea	1.248	78.0
" Mediterranean	1.029	64.3
Wax, bees'	.965	60.5
" shoemaker's	.897	56.1
Whey, cow's	1.019	65.0
White oak, upland	.687	42.9
" " James River	.759	47.3
Willow, .585 to .486	.535	33.4
Wine, Bordeaux	.993	62.1
" Burgundy	.991	62.0
" Champagne (white)	.997	62.3
" Constance	1.081	67.6
" Madeira	1.038	65.0
" Malaga	1.022	64.0
" Port	.997	62.3
Wolfram	7.119	445.0
Woodstone, 2.045 to 2.675	2.360	147.5
Yew, Dutch	.788	49.2
" Spanish	.807	50.4
Zeolite	2.400	150.0
Zircon	4.542	284.0
Zinc, cast	6.861	428.8
" rolled	7.191	449.4

Mensuration.

Mensuration of Surfaces.

Area of any parallelogram	= base × perpendicular height.
Area of any triangle	= base × $\frac{1}{2}$ perpendicular height.
Area of any circle	= diameter^2 × .7854.
Area of sector of circle	= arc × $\frac{1}{2}$ radius.
Area of segment of circle	= area of sector of equal radius less area of triangle.
Area of parabola	= base × $\frac{2}{3}$ height.
Area of ellipse	= longest diameter × shortest diameter × .7854.
Area of cycloid	= area of generating circle × 3.
Area of any regular polygon	= sum of its sides × perpendicular from its centre to one of its sides ÷ 2.
Surface of cylinder	= area of both ends + length × circumference.
Surface of cone	= area of base + circumference of base × $\frac{1}{2}$ slant height.
Surface of sphere	= diameter^2 × 3.1415.
Surface of frustum	= sum of girth at both ends × $\frac{1}{2}$ slant height + area of both ends.
Surface of cylindrical ring	= thickness of ring added to the inner diameter × by the thickness × 9.8698.
Surface of segment	= height of segment × whole circumference of sphere of which it is a part.

Polygons.

1. To find the area of any regular polygon. Square one of its sides, and multiply said square by the number in column 1 of the following table.

2. Having a side of a regular polygon, to find the radius of a circumscribing circle. Multiply the side by the corresponding number in column 2.

3. Having the radius of a circumscribing circle, to find the side of the inscribed regular polygon. Multiply the radius by the corresponding number in column 3.

Number of Sides.	Name of Polygon.	1 Area $= S^2X$.	2 Radius $= SX$.	3 Side $= RX$.	Angle contained between Two Sides.
3	Equilateral triangle	.433	.5774	1.732	60°
4	Square	1.0	.7071	1.4142	90°
5	Pentagon	1.7205	.8507	1.1756	108°
6	Hexagon	2.5891	1.0	1.0	120°
7	Heptagon	3.6339	1.1524	.8678	128.57°
8	Octagon	4.8284	1.3066	.7654	135°
9	Nonagon	6.1818	1.4619	.684	140°
10	Decagon	7.6942	1.618	.618	144°
11	Undecagon	9.3656	1.7747	.5635	147.27°
12	Dodecagon	11.1962	1.9319	.5176	150°

In the heads of the columns in above table S = side, and R = radius.

Mensuration of Solids.

Cylinder	= area of one end × length.
Sphere	= cube of diameter × .5236.
Segment of sphere	= square root of the height added to three times the square of the radius of base × by height and × .5236.
Cone or pyramid	= area of base × ⅓ height.
Frustum of a cone	= product of diameter of both ends + sum of their squares × perpendicular height × .2618.
Frustum of a pyramid	= sum of the areas of the two ends + square root of their product × ⅓ of the perpendicular height.
Solidity of a wedge	= area of base × ½ height.
Frustum of a wedge	= ½ height × sum of the areas of the two ends.
Solidity of a ring	= thickness + inner diameter × square of the thickness × 2.4674.

POLYHEDRONS.

No. of Sides.	Names.	1 Radius of Circumscribed Circle.	2 Radius of Inscribed Circle.	3 Area of Surface.	4 Cubic Contents.
4	Tetrahedron....	.6124	.2041	1.7320	.1178
6	Hexahedron....	.866	.5	6.	1.
8	Octahedron	.7071	.4082	3.4641	.4714
12	Dodecahedron..	1.4012	1.1135	20.6458	7.6631
20	Icosahedron.....	.951	.7558	86.602	2.1817

Side is length of linear edge of any side of the figure.

Radius of circumscribed circle = *side* × the number in column 1 corresponding to the figure.

Radius of inscribed circle = *side* × the number in column 2 corresponding to the figure.

Area of surface = square of side × the number in column 3 corresponding to the figure.

Cubic contents = cube of side × the number in column 4 corresponding to the figure.

PROPERTIES OF THE CIRCLE.

Diameter	× 3.14159	= circumference.
"	× .8862	= side of an equal square.
"	× .7071	= " " " inscribed square.
Diameter^2	× .7854	= area of circle.
Radius	× 6.28318	= circumference.
Circumference	÷ 3.14159	= diameter.

The circle contains a greater area than any plane figure bounded by an equal perimeter or outline.

The areas of circles are to each other as the squares of their diameters.

Any circle whose diameter is double that of another contains four times the area of the other.

The area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

TABLE 81.

AREAS AND CIRCUMFERENCE OF CIRCLES.

Diam. In.	Circumf. In.	Area. Sq. In.	Diam. In.	Circumf. In.	Area. Sq. In.	Diam. In.	Circumf. In.	Area. Sq. In.
1/64	.049087	.00019	2 ⅝	8.24668	5.4119	6 ⅝	20.8131	34.472
1/32	.098175	.00077	11/16	8.44303	5.6727	¾	21.2058	35.785
3/64	.147262	.00173	¾	8.63938	5.9396	⅞	21.5984	37.122
1/16	.196350	.00307	13/16	8.83573	6.2126	7	21.9911	38.485
3/32	.294524	.00690	⅞	9.03208	6.4918	⅛	22.3838	39.871
⅛	.392699	.01227	15/16	9.22843	6.7771	¼	22.7765	41.282
5/32	.490874	.01917	3	9.42478	7.0686	⅜	23.1692	42.718
3/16	.589049	.02761	1	9.62113	7.3662	½	23.5619	44.179
7/32	.687223	.03758		9.81748	7.6699	⅝	23.9546	45.664
¼	.785398	.04909	3	10.0138	7.9798	¾	24.3473	47.173
9/32	.883573	.06213		10.2102	8.2958	⅞	24.7400	48.707
5/16	.981748	.07670	5	10.4065	8.6179	8	25.1327	50.265
11/32	1.07992	.09281		10.6029	8.9462	⅛	25.5254	51.849
⅜	1.17810	.11045	7	10.7992	9.2806	¼	25.9181	53.456
13/32	1.27627	.12962		10.9956	9.6211	⅜	26.3108	55.088
7/16	1.37445	.15033	9	11.1919	9.9678	½	26.7035	56.745
15/32	1.47262	.17257		11.3883	10.321	⅝	27.0962	58.426
½	1.57080	.19635	11	11.5846	10.680	¾	27.4889	60.132
17/32	1.66897	.22166		11.7810	11.045	⅞	27.8816	61.862
9/16	1.76715	.24850	13	11.9773	11.416	9	28.2743	63.617
19/32	1.86532	.27688		12.1737	11.793	⅛	28.6670	65.397
⅝	1.96350	.30680	15	12.3700	12.177	¼	29.0597	67.201
21/32	2.06167	.33824	4	12.5664	12.566	⅜	29.4524	69.029
11/16	2.15984	.37122	1/16	12.7627	12.962	½	29.8451	70.882
23/32	2.25802	.40574	⅛	12.9591	13.364	⅝	30.2378	72.760
¾	2.35619	.44179	3/16	13.1554	13.772	¾	30.6305	74.662
25/32	2.45437	.47937	¼	13.3518	14.186	⅞	31.0232	76.589
13/16	2.55254	.51849	5/16	13.5481	14.607	10	31.4159	78.540
27/32	2.65072	.55914	⅜	13.7445	15.033	⅛	31.8086	80.516
⅞	2.74889	.60132	7/16	13.9408	15.466	¼	32.2013	82.516
29/32	2.84707	.64504	½	14.1372	15.904	⅜	32.5940	84.541
15/16	2.94524	.69029	9/16	14.3335	16.349	½	32.9867	86.590
31/32	3.04342	.73708	⅝	14.5299	16.800	⅝	33.3794	88.664
1	3.14159	.78540	11/16	14.7262	17.257	¾	33.7721	90.763
1/16	3.33794	.88664	¾	14.9226	17.721	⅞	34.1648	92.886
⅛	3.53429	.99402	13/16	15.1189	18.190	11	34.5575	[illegible]
3/16	3.73064	1.1075	⅞	15.3153	18.665	⅛	34.9502	97.205
¼	3.92699	1.2272	15/16	15.5116	19.147	¼	35.3429	99.402
5/16	4.12334	1.3530	5	15.7080	19.635	⅜	35.7356	101.62
⅜	4.31969	1.4849	1/16	15.9043	20.129	½	36.1283	103.87
7/16	4.51604	1.6230	⅛	16.1007	20.629	⅝	36.5210	106.14
½	4.71239	1.7671	3/16	16.2970	21.135	¾	36.9137	108.43
9/16	4.90874	1.9175	¼	16.4934	21.648	⅞	37.3064	110.75
⅝	5.10509	2.0739	5/16	16.6897	22.166	12	37.6991	113.10
11/16	5.30144	2.2365	⅜	16.8861	22.691	⅛	38.0918	115.47
¾	5.49779	2.4053	7/16	17.0824	23.221	¼	38.4845	117.86
13/16	5.69414	2.5802	½	17.2788	23.758	⅜	38.8772	120.28
⅞	5.89049	2.7612	9/16	17.4751	24.301	½	39.2699	122.72
15/16	6.08684	2.9483	⅝	17.6715	24.850	⅝	39.6626	125.19
2	6.28319	3.1416	11/16	17.8678	25.406	¾	40.0553	127.68
1/16	6.47953	3.3410	¾	18.0642	25.967	⅞	40.4480	130.19
⅛	6.67588	[illegible]	13/16	18.2605	26.535	13	40.8407	132.73
3/16	6.87223	3.7583	⅞	18.4569	27.109	⅛	41.2334	135.30
¼	7.06858	3.9761	15/16	18.6532	27.688	¼	41.6261	137.89
5/16	7.26493	4.2000	6	18.8496	28.274	⅜	42.0188	140.50
⅜	7.46128	4.4301	⅛	19.2423	29.465	½	42.4115	143.14
7/16	7.65763	4.6664	¼	19.6350	30.680	⅝	42.8042	145.80
½	7.85398	4.9087	⅜	20.0277	31.919	¾	43.1969	148.49
9/16	8.05033	5.1572	½	20.4204	33.183	⅞	43.5896	151.20

AREAS AND CIRCUMFERENCE OF CIRCLES. (*Continued.*)

Diam. In.	Circumf. In.	Area. Sq. In.	Diam. In.	Circumf. In.	Area. Sq. In.	Diam. In.	Circumf. In.	Area. Sq. In.
14	43.9823	153.94	21⅝	67.9369	367.28	29¼	91.8916	671.96
⅛	44.3750	156.70	¾	68.3296	371.54	⅜	92 2843	677.71
¼	44.7677	159.48	⅞	68.7223	375.83	½	92.6770	683.49
⅜	45.1604	162.30	22	69.1150	380.13	⅝	93.0697	689.30
½	45.5531	165.13	⅛	69.5077	384.46	¾	93.4624	695.13
⅝	45.9458	167.99	¼	C9 9004	388.82	⅞	93.8551	700.98
¾	46.3385	170.87	⅜	70.2931	393.20	30	94.2478	706.86
⅞	46.7312	173.78	½	70.6858	397.61	⅛	94.6405	712.76
15	47.1239	176.71	⅝	71.0785	402.04	¼	95.0332	718.69
⅛	47.5166	179.67	¾	71.4712	406.49	⅜	95.4259	724.64
¼	47.9093	182.65	⅞	71.8639	410.97	½	95.8186	730.62
⅜	48.3020	185.66	23	72.2566	415.48	⅝	96.2113	736.62
½	48.6947	188 69	⅛	72.6493	420.00	¾	96.6040	742.64
⅝	49.0874	191.75	¼	73.0420	424.56	⅞	96.9967	748.69
¾	49.4801	194.83	⅜	73.4347	429.13	31	97.3894	754.77
⅞	49.8728	197.93	½	73.8274	433.74	⅛	97.7821	760.87
16	50.2655	201.06	⅝	74.2201	438.36	¼	98.1748	766.99
⅛	50.6582	204.22	¾	74.6128	443.01	⅜	98 5675	773.14
¼	51.0509	207.39	⅞	75.0055	447.69	½	98.9602	779.31
⅜	51.4436	210.60	24	75.3982	452.39	⅝	99.3529	785.51
½	51.8363	213.82	⅛	75.7909	457.11	¾	99.7456	791.73
⅝	52.2290	217.08	¼	76.1836	461.86	⅞	100.138	797.98
¾	52.6217	220.35	⅜	76.5763	466.64	32	100.531	804.25
⅞	53.0144	223.65	½	76.9690	471.44	⅛	100.924	810.54
17	53.4071	226.98	⅝	77.3617	476.26	¼	101.316	816.86
⅛	53.7998	230.33	¾	77.7544	481.11	⅜	101.709	823.21
¼	54.1925	233.71	⅞	78.1471	485.98	½	102.102	829.58
⅜	54.5852	237.10	25	78.5398	490.87	⅝	102.494	835.97
½	54.9779	240.53	⅛	78.9325	495.79	¾	102.887	842.39
⅝	55.3706	243 98	¼	79.3252	500.74	⅞	103.280	848.83
¾	55.7633	247.45	⅜	79.7179	505.71	33	103.673	855.30
⅞	56.1560	250.95	½	80.1106	510.71	⅛	104.065	861.79
18	56.5487	254.47	⅝	80.5033	515.72	¼	104.458	868.31
⅛	56.9414	258.02	¾	80.8960	520.77	⅜	104.851	874.85
¼	57.3341	261.59	⅞	81 2887	525.84	½	105.243	881.41
⅜	57.7268	265.18	26	81.6814	530.93	⅝	105.636	888.00
½	58.1195	268.80	⅛	82.0741	536.05	¾	106.029	894.62
⅝	58.5122	272.45	¼	82.4668	541.19	⅞	106.421	901.26
¾	58.9049	276.12	⅜	82.8595	546.35	34	106.814	907.92
⅞	59.2976	279.81	½	83.2522	551.55	⅛	107.207	914.61
19	59.6903	283.53	⅝	83.6449	556.76	¼	107.600	921.32
⅛	60.0830	287.27	¾	84.0376	562.00	⅜	107.992	928.06
¼	60.4757	291.04	⅞	84.4303	567.27	½	108.385	934.82
⅜	60.8684	294.83	27	84.8230	572.56	⅝	108.778	941.61
½	61.2611	298.65	⅛	85.2157	577.87	¾	109.170	948.42
⅝	61.6538	302.49	¼	85.6084	583.21	⅞	109.563	955.25
¾	62.0465	306.35	⅜	86.0011	588.57	35	109.956	962.11
⅞	62.4392	310.24	½	86.3938	593.96	⅛	110.348	969.00
20	62.8319	314.16	⅝	86.7865	599.37	¼	110.741	975.91
⅛	63.2246	318.10	¾	87.1792	604.81	⅜	111.134	982.84
¼	63.6173	322.06	⅞	87.5719	610.27	½	111.527	989 80
⅜	64.0100	326.05	28	87.9646	615.65	⅝	111.919	996.78
½	64.4026	330.06	⅛	88.3573	621.26	¾	112.312	1003.8
⅝	64.7953	334.10	¼	88.7500	626.80	⅞	112.705	1010.8
¾	66.1880	338.16	⅜	89.1427	632.36	36	113.097	1017.9
⅞	65.5807	342.25	½	89.5354	637.94	⅛	113.490	1025.0
21	65.9734	346.36	⅝	89.9281	643.55	¼	113.883	1032.1
⅛	66.3661	350.50	¾	90.3208	649.18	⅜	114.275	1039.2
¼	66.7588	354.66	⅞	90.7135	654.84	½	114.668	1046.3
⅜	67.1515	358.84	29	91.1062	660.52	⅝	115.061	1053.5
½	67.5442	363.05	⅛	91.4989	666.23	¾	115.454	1060.7

AREAS AND CIRCUMFERENCE OF CIRCLES. (*Continued.*)

Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.
36⅞	115.846	1068.0	44½	139.801	1555.3		163.756	2133.9
37	116.239	1075.2	⅝	140.194	1564.0		164.148	2144.2
⅛	116.632	1082.5	¾	140.586	1572.8		164.541	2154.5
¼	117.024	1089.8	⅞	140.979	1581.6		164.934	2164.8
⅜	117.417	1097.1	45	141.372	1590.4		165.326	2175.1
½	117.810	1104.5	⅛	141.764	1599.3		165.719	2185.4
⅝	118.202	1111.8	¼	142.157	1608.2		166.112	2195.8
¾	118.596	1119.2	⅜	142.550	1617.0		166.504	2206.2
⅞	118.988	1126.7	½	142.942	1626.0		166.897	2216.6
38	119.381	1134.1	⅝	143.335	1634.9		167.290	2227.0
⅛	119.773	1141.6	¾	143.728	1643.9		167.683	2237.5
¼	120.166	1149.1	⅞	144.121	1652.9		168.075	2248.0
⅜	120.559	1156.6	46	144.513	1661.9		168.468	2258.5
½	120.951	1164.2	⅛	144.906	1670.9		168.861	2269.1
⅝	121.344	1171.7	¼	145.299	1680.0		169.253	2279.6
¾	121.737	1179.3	⅜	145.691	1689.1		169.646	2290.2
⅞	122.129	1186.9	½	146.084	1698.2		170.039	2300.8
39	122.522	1194.6	⅝	146.477	1707.4		170.431	2311.5
⅛	122.915	1202.3	¾	146.869	1716.5		170.824	2322.1
¼	123.308	1210.0	⅞	147.262	1725.7		171.217	2332.8
⅜	123.700	1217.7	47	147.655	1734.9		171.609	2343.5
½	124.093	1225.4	⅛	148.048	1744.2		172.002	2354.3
⅝	124.486	1233.2	¼	148.440	1753.5		172.395	2365.0
¾	124.878	1241.0	⅜	148.833	1762.7		172.788	2375.8
⅞	125.271	1248.8	½	149.226	1772.1		173.180	2386.6
40	125.664	1256.6	⅝	149.618	1781.4		173.573	2397.5
⅛	126.056	1264.5	¾	150.011	1790.8		173.966	2408.3
¼	126.449	1272.4	⅞	150.404	1800.1		174.358	2419.2
⅜	126.842	1280.3	48	150.796	1809.6		174.751	2430.1
½	127.235	1288.2	⅛	151.189	1819.0		175.144	2441.1
⅝	127.627	1296.2	¼	151.582	1828.5		175.536	2452.0
¾	128.020	1304.2	⅜	151.975	1837.9	—	175.929	2463.0
⅞	128.413	1312.2	½	152.367	1847.5	⅛	176.322	2474.0
41	128.805	1320.3	⅝	152.760	1857.0	¼	176.715	2485.0
⅛	129.198	1328.3	¾	153.153	1866.5	⅜	177.107	2496.1
¼	129.591	1336.4	⅞	153.545	1876.1	½	177.500	2507.2
⅜	129.983	1344.5	49	153.938	1885.7	⅝	177.893	2518.3
½	130.376	1352.7	⅛	154.331	1895.4	¾	178.285	2529.4
⅝	130.769	1360.8	¼	154.723	1905.0	⅞	178.678	2540.6
¾	131.161	1369.0	⅜	155.116	1914.7	57	179.071	2551.8
⅞	131.554	1377.2	½	155.509	1924.4	⅛	179.463	2563.0
42	131.947	1385.4	⅝	155.902	1934.2	¼	179.856	2574.2
⅛	132.340	1393.7	¾	156.294	1943.9	⅜	180.249	2585.4
¼	132.732	1402.0	⅞	156.687	1953.7	½	180.642	2596.7
⅜	133.125	1410.3	50	157.080	1963.5	⅝	181.034	2608.0
½	133.518	1418.6	⅛	157.472	1973.3	¾	181.427	2619.4
⅝	133.910	1427.0	¼	157.865	1983.2	⅞	181.820	2630.7
¾	134.303	1435.4	⅜	158.258	1993.1	58	182.212	2642.1
⅞	134.696	1443.8	½	158.650	2003.0	⅛	182.605	2653.5
43	135.088	1452.2	⅝	159.043	2012.9	¼	182.998	2664.9
⅛	135.481	1460.7	¾	159.436	2022.8	⅜	183.390	2676.4
¼	135.874	1469.1	⅞	159.829	2032.8	½	183.783	2687.8
⅜	136.267	1477.6	51	160.221	2042.8	⅝	184.176	2699.3
½	136.659	1486.2	⅛	160.614	2052.8	¾	184.569	2710.9
⅝	137.052	1494.7	¼	161.007	2062.9	⅞	184.961	2722.4
¾	137.445	1503.3	⅜	161.399	2073.0	59	185.354	2734.0
⅞	137.837	1511.9	½	161.792	2083.1	⅛	185.747	2745.6
44	138.230	1520.5	⅝	162.185	2093.2	¼	186.139	2757.2
⅛	138.623	1529.2	¾	162.577	2103.3	⅜	186.532	2768.8
¼	139.015	1537.9	⅞	162.970	2113.5	½	186.925	2780.5
⅜	139.408	1546.6	52	163.363	2123.7	⅝	187.317	2792.2

AREAS AND CIRCUMFERENCE OF CIRCLES. *(Continued.)*

Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.
59¾	187.710	2803.9	67⅜	211.665	3565.2	75	235.619	4417.9
⅞	188.103	2815.7	½	212.058	3578.5	⅛	236.012	4432.6
60	188.496	2827.4	⅝	212.450	3591.7	¼	236.405	4447.4
⅛	188.888	2839.2	¾	212.843	3605.0	⅜	236.798	4462.2
¼	189.281	2851.0	⅞	213.236	3618.3	½	237.190	4477.0
⅜	189.674	2862.9	68	213.628	3631.7	⅝	237.583	4491.8
½	190.066	2874.8		214.021	3645.0	¾	237.976	4506.7
⅝	190.459	2886.6		214.414	3658.4	⅞	238.368	4521.5
¾	190.852	2898.6		214.806	3671.8	76	238.761	4536.5
⅞	191.244	2910.5		215.199	3685.3	⅛	239.154	4551.4
61	191.637	2922.5		215.592	3698.7	¼	239.546	4566.4
⅛	192.030	2934.5		215.984	3712.2	⅜	239.939	4581.3
¼	192.423	2946.5		216.377	3725.7	½	240.332	4596.3
⅜	192.815	2958.5		216.770	3739.3	⅝	240.725	4611.5
½	193.208	2970.5		217.163	3752.8	¾	241.117	4626.4
⅝	193.601	2982.7		217.555	3766.4	⅞	241.510	4641.5
¾	193.993	2994.8		217.948	3780.0	77	241.903	4656.6
⅞	194.386	3006.9		218.341	3793.7	⅛	242.295	4671.8
62	194.779	3019.1		218.733	3807.3	¼	242.688	4686.9
⅛	195.171	3031.3		219.126	3821.0	⅜	243.081	4702.1
¼	195.564	3043.5		219.519	3834.7	½	243.473	4717.3
⅜	195.957	3055.7		219.911	3848.5	⅝	243.866	4732.5
½	196.350	3068.0		220.304	3862.2	¾	244.259	4747.8
⅝	196.742	3080.3		220.697	3876.0	⅞	244.652	4763.1
¾	197.135	3092.6		221.090	3889.8	78	245.044	4778.4
⅞	197.528	3104.9		221.482	3903.6	⅛	245.437	4793.7
63	197.920	3117.2		221.875	3917.5	¼	245.830	4809.0
⅛	198.313	3129.6		222.268	3931.4	⅜	246.222	4824.4
¼	198.706	3142.0		222.660	3945.3	½	246.615	4839.8
⅜	199.098	3154.5		223.053	3959.2	⅝	247.008	4855.2
½	199.491	3166.9		223.446	3973.1	¾	247.400	4870.7
⅝	199.884	3179.4		223.838	3987.1	⅞	247.793	4886.2
¾	200.277	3191.9		224.231	4001.1	79	248.186	4901.7
⅞	200.669	3204.4		224.624	4015.2	⅛	248.579	4917.2
64	201.062	3217.0		225.017	4029.2	¼	248.971	4932.7
⅛	201.455	3229.6		225.409	4043.3	⅜	249.364	4948.3
¼	201.847	3242.2		225.802	4057.4	½	249.757	4963.9
⅜	202.240	3254.8		226.195	4071.5	⅝	250.149	4979.5
½	202.633	3267.5		226.587	4085.7	¾	250.542	4995.2
⅝	203.025	3280.1		226.980	4099.8	⅞	250.935	5010.9
¾	203.418	3292.8		227.373	4114.0	80	251.327	5026.5
⅞	203.811	3305.6		227.765	4128.2	⅛	251.720	5042.3
65	204.204	3318.3		228.158	4142.5	¼	252.113	5058.0
⅛	204.596	3331.1		228.551	4156.8	⅜	252.506	5073.8
¼	204.989	3343.9		228.944	4171.1	½	252.898	5089.6
⅜	205.382	3356.7		229.336	4185.4	⅝	253.291	5105.4
½	205.774	3369.6	⅛	229.729	4199.7	¾	253.684	5121.2
⅝	206.167	3382.4	¼	230.122	4214.1	⅞	254.076	5137.1
¾	206.560	3395.3	⅜	230.514	4228.5	81	254.469	5153.0
⅞	206.952	3408.3	½	230.907	4242.9	⅛	254.862	5168.9
66	207.345	3421.2	⅝	231.300	4257.4	¼	255.254	5184.9
⅛	207.738	3434.2	¾	231.692	4271.8	⅜	255.647	5200.8
¼	208.131	3447.2	⅞	232.085	4286.3	½	256.040	5216.8
⅜	208.523	3460.2	74	232.478	4300.8	⅝	256.433	5232.8
½	208.916	3473.2	⅛	232.871	4315.4	¾	256.825	5248.9
⅝	209.309	3486.3	¼	233.263	4329.9	⅞	257.218	5264.9
¾	209.701	3499.4	⅜	233.656	4344.5	82	257.611	5281.0
⅞	210.094	3512.5	½	234.049	4359.2	⅛	258.003	5297.1
67	210.487	3525.7	⅝	234.441	4373.8	¼	258.396	5313.3
⅛	210.879	3538.8	¾	234.834	4388.5	⅜	258.789	5329.4
¼	211.272	3552.0	⅞	235.227	4403.1	½	259.181	5345.6

AREAS AND CIRCUMFERENCE OF CIRCLES. *(Continued.)*

Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.	Diam. In.	Cir-cumf. In.	Area. Sq. In.
82⅝	259.574	5361.8	88½	278.031	6151.4	94⅜	296.488	6995.3
¾	259.967	5378.1	⅝	278.424	6168.8	½	296.881	7013.8
⅞	260.359	5394.3	¾	278.816	6186.2	⅝	297.273	7032.4
83	260.752	5410.6	⅞	279.209	6203.7	¾	297.666	7051.0
⅛	261.145	5426.9	89	279.602	6221.1	⅞	298.059	7069.6
¼	261.538	5443.3	⅛	279.994	6238.6	95	298.451	7088.2
⅜	261.930	5459.6	¼	280.387	6256.1	⅛	298.844	7106.9
½	262.323	5476.0	⅜	280.780	6273.7	¼	299.237	7125.6
⅝	262.716	5492.4	½	281.173	6291.2	⅜	299.629	7144.3
¾	263.108	5508.8	⅝	281.565	6308.8	½	300.022	7163.0
⅞	263.501	5525.3	¾	281.958	6326.4	⅝	300.415	7181.8
84	263.894	5541.8	⅞	282.351	6344.1	¾	300.807	7200.6
⅛	264.286	5558.3	90	282.743	6361.7	⅞	301.200	7219.4
¼	264.679	5574.8	⅛	283.136	6379.4	96	301.593	7238.2
⅜	265.072	5591.4	¼	283.529	6397.1	⅛	301.986	7257.1
½	265.465	5607.9	⅜	283.921	6414.9	¼	302.378	7276.0
⅝	265.857	5624.5	½	284.314	6432.6	⅜	302.771	7294.9
¾	266.250	5641.2	⅝	284.707	6450.4	½	303.164	7313.8
⅞	266.643	5657.8	¾	285.100	6468.2	⅝	303.556	7332.8
85	267.035	5674.5	⅞	285.492	6486.0	¾	303.949	7351.8
⅛	267.428	5691.2	91	285.885	6503.9	⅞	304.342	7370.8
¼	267.821	5707.9	⅛	286.278	6521.8	97	304.734	7389.8
⅜	268.213	5724.7	¼	286.670	6539.7	⅛	305.127	7408.9
½	268.606	5741.5	⅜	287.063	6557.6	¼	305.520	7428.0
⅝	268.999	5758.3	½	287.456	6575.5	⅜	305.913	7447.1
¾	269.392	5775.1	⅝	287.848	6593.5	½	306.305	7466.2
⅞	269.784	5791.9	¾	288.241	6611.5	⅝	306.698	7485.3
86	270.177	5808.8	⅞	288.634	6629.6	¾	307.091	7504.5
⅛	270.570	5825.7	92	289.027	6647.6	⅞	307.483	7523.7
¼	270.962	5842.6	⅛	289.419	6665.7	98	307.876	7543.0
⅜	271.355	5859.6	¼	289.812	6683.8	⅛	308.269	7562.2
½	271.748	5876.5	⅜	290.205	6701.9	¼	308.661	7581.5
⅝	272.140	5893.5	½	290.597	6720.1	⅜	309.054	7600.8
¾	272.533	5910.6	⅝	290.990	6738.2	½	309.447	7620.1
⅞	272.926	5927.6	¾	291.383	6756.4	⅝	309.840	7639.5
87	273.319	5944.7	⅞	291.775	6774.7	¾	310.232	7658.9
⅛	273.711	5961.8	93	292.168	6792.9	⅞	310.625	7678.3
¼	274.104	5978.9	⅛	292.561	6811.2	99	311.018	7697.7
⅜	274.497	5996.0	¼	292.954	6829.5	⅛	311.410	7717.1
½	274.889	6013.2	⅜	293.346	6847.8	¼	311.803	7736.6
⅝	275.282	6030.4	½	293.739	6866.1	⅜	312.196	7756.1
¾	275.675	6047.6	⅝	294.132	6884.5	½	312.588	7775.6
⅞	276.067	6064.9	¾	294.524	6902.9	⅝	312.981	7795.2
88	276.460	6082.1	⅞	294.917	6921.3	¾	313.374	7814.8
⅛	276.853	6099.4	94	295.310	6939.8	⅞	313.767	7834.4
¼	277.246	6116.7	⅛	295.702	6958.2	100	314.159	7854.0
⅜	277.638	6134.1	¼	296.096	6976.7			

TABLE 82.
SQUARE ROOTS AND CUBE ROOTS OF NUMBERS.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	1	1	1.0000000	1.0000000	1.000000000
2	4	8	1.4142136	1.2599210	.500000000
3	9	27	1.7320508	1.4422496	.333333333
4	16	64	2.0000000	1.5874011	.250000000
5	25	125	2.2360680	1.7099759	.200000000
6	36	216	2.4494897	1.8171206	.166666667
7	49	343	2.6457513	1.9129312	.142857143
8	64	512	2.8284271	2.0000000	.125000000
9	81	729	3.0000000	2.0800837	.111111111
10	100	1000	3.1622777	2.1544347	.100000000
11	121	1331	3.3166248	2.2239801	.090909091
12	144	1728	3.4641016	2.2894286	.083333333
13	169	2197	3.6055513	2.3513347	.076923077
14	196	2744	3.7416574	2.4101422	.071428571
15	225	3375	3.8729833	2.4662121	.066666667
16	256	4096	4.0000000	2.5198421	.062500000
17	289	4913	4.1231056	2.5712816	.058823529
18	324	5832	4.2426407	2.6207414	.055555556
19	361	6859	4.3588989	2.6684016	.052631579
20	400	8000	4.4721360	2.7144177	.050000000
21	441	9261	4.5825757	2.7589243	.047619048
22	484	10648	4.6904158	2.8020393	.045454545
23	529	12167	4.7958315	2.8438670	.043478261
24	576	13824	4.8989795	2.8844991	.041666667
25	625	15625	5.0000000	2.9240177	.040000000
26	676	17576	5.0990195	2.9624960	.038461538
27	729	19683	5.1961524	3.0000000	.037037037
28	784	21952	5.2915026	3.0365889	.035714286
29	841	24389	5.3851648	3.0723168	.034482759
30	900	27000	5.4772256	3.1072325	.033333333
31	961	29791	5.5677644	3.1413806	.032258065
32	1024	32768	5.6568542	3.1748021	.031250000
33	1089	35937	5.7445626	3.2075343	.030303030
34	1156	39304	5.8309519	3.2396118	.029411765
35	1225	42875	5.9160798	3.2710663	.028571429
36	1296	46656	6.0000000	3.3019272	.027777778
37	1369	50653	6.0827625	3.3322218	.027027027
38	1444	54872	6.1644140	3.3619754	.026315789
39	1521	59319	6.2449980	3.3912114	.025641026
40	1600	64000	6.3245553	3.4199519	.025000000
41	1681	68921	6.4031242	3.4482172	.024390244
42	1764	74088	6.4807407	3.4760266	.023809524
43	1849	79507	6.5574385	3.5033981	.023255814
44	1936	85184	6.6332496	3.5303483	.022727273
45	2025	91125	6.7082039	3.5568933	.022222222
46	2116	97336	6.7823300	3.5830479	.021739130
47	2209	103823	6.8556546	3.6088261	.021276600
48	2304	110592	6.9282032	3.6342411	.020833333
49	2401	117649	7.0000000	3.6593057	.020408163
50	2500	125000	7.0710678	3.6840314	.020000000
51	2601	132651	7.1414284	3.7084298	.019607843
52	2704	140608	7.2111026	3.7325111	.019230769
53	2809	148877	7.2801099	3.7562858	.018867925
54	2916	157464	7.3484692	3.7797631	.018518519
55	3025	166375	7.4161985	3.8029525	.018181818
56	3136	175616	7.4833148	3.8258624	.017857143
57	3249	185193	7.5498344	3.8485011	.017543860
58	3364	195112	7.6157731	3.8708766	.017241379
59	3481	205379	7.6811457	3.8929965	.016949153
60	3600	216000	7.7459667	3.9148676	.016666667
61	3721	226981	7.8102497	3.9364972	.016393443
	3844	238328	7.8740079	3.9578915	.016129032

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
					015873016
					015625000
					015384615
					015151515
					014925373
					014705882
					014492754
					014285714
					014084507
					013888889
					013698630
					013513514
					013333333
					013157895
					012987013
					012820513
					012658228
					012500000
					012345679
					012195122
					012048193
					011904762
					011764706
					011627907
					011494253
					011363636
					011235955
					011111111
					010989011
					010869565
					010752688
					010638298
					010526316
					010416667
					010309278
					010204082
					010101010
					010000000
					009900990
					009803922
					009708738
					009615385
					009523810
					009433962
					009345794
					009259259
					009174312
					009090909
					009009009
					008928571
					008849558
					008771930
					008695652
					008620690
					008547009
					008474576
					008403361
					008333333
					008264463
					008196721
					00

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
125	15625	1953125	11.1803399	5.0000000	.008000000
126	15876	2000376	11.2249722	5.0132979	.007936508
127	16129	2048383	11.2694277	5.0265257	.007874016
128	16384	2097152	11.3137085	5.0396842	.007812500
129	16641	2146689	11.3578167	5.0527743	.007751938
130	16900	2197000	11.4017543	5.0657970	.007692308
131	17161	2248091	11.4455231	5.0787531	.007633588
132	17424	2299968	11.4891253	5.0916434	.007575758
133	17689	2352637	11.5325626	5.1044687	.007518797
134	17956	2406104	11.5758369	5.1172299	.007462687
135	18225	2460375	11.6189500	5.1299278	.007407407
136	18496	2515456	11.6619038	5.1425632	.007352941
137	18769	2571353	11.7046999	5.1551367	.007299270
138	19044	2628072	11.7473401	5.1676493	.007246377
139	19321	2685619	11.7898261	5.1801015	.007194245
140	19600	2744000	11.8321596	5.1924941	.007142857
141	19881	2803221	11.8743421	5.2048279	.007092199
142	20164	2863288	11.9163753	5.2171034	.007042254
143	20449	2924207	11.9582607	5.2293215	.006993007
144	20736	2985984	12.0000000	5.2414828	.006944444
145	21025	3048625	12.0415946	5.2535879	.006896552
146	21316	3112136	12.0830460	5.2656374	.006849315
147	21609	3176523	12.1243557	5.2776321	.006802721
148	21904	3241792	12.1655251	5.2895725	.006756757
149	22201	3307949	12.2065556	5.3014592	.006711409
150	22500	3375000	12.2474487	5.3132928	.006666667
151	22801	3442951	12.2882057	5.3250740	.006622517
152	23104	3511808	12.3288280	5.3368033	.006578947
153	23409	3581577	12.3693169	5.3484812	.006535948
154	23716	3652264	12.4096736	5.3601084	.006493506
155	24025	3723875	12.4498996	5.3716854	.006451613
156	24336	3796416	12.4899960	5.3832126	.006410256
157	24649	3869893	12.5299641	5 3946907	.006369427
158	24964	3944312	12.5698051	5.4061202	.006329114
159	25281	4019679	12.6095202	5.4175015	.006289308
160	25600	4096000	12.6491106	5.4288352	.006250000
161	25921	4173281	12.6885775	5.4401218	.006211180
162	26244	4251528	12.7279221	5.4513618	.006172840
163	26569	4330747	12.7671453	5.4625556	.006134969
164	26896	4410944	12.8062485	5.4737037	.006097561
165	27225	4492125	12.8452326	5.4848066	.006060606
166	27556	4574296	12.8840987	5.4958647	.006024096
167	27889	4657463	12.9228480	5.5068784	.005988024
168	28224	4741632	12.9614814	5.5178484	.005952381
169	28561	4826809	13.0000000	5.5287748	.005917160
170	28900	4913000	13.0384048	5.5396583	.005882353
171	29241	5000211	13.0766968	5.5504991	.005847953
172	29584	5088448	13.1148770	5.5612978	.005813953
173	29929	5177717	13.1529464	5.5720546	.005780347
174	30276	5268024	13.1909060	5.5827702	.005747126
175	30625	5359375	13.2287566	5.5934447	.005714286
176	30976	5451776	13.2664992	5.6040787	.005681818
177	31329	5545233	13.3041347	5.6146724	.005649718
178	31684	5639752	13.3416641	5.6252263	.005617978
179	32041	5735339	13.3790882	5.6357408	.005586592
180	32400	5832000	13.4164079	5.6462162	.005555556
181	32761	5929741	13.4536240	5.6566528	.005524862
182	33124	6028568	13.4907376	5.6670511	.005494505
183	33489	6128487	13.5277493	5.6774114	.005464481
184	33856	6229504	13.5646600	5.6877340	.005434783
185	34225	6331625	13.6014705	5.6980192	.005405405
186	34596	6434856	13.6381817	5.7082675	.005376344

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

187	34969	6539203	13.6747943	5.7184791	.005347594
188	35344	6644672	13.7113092	5.7286543	.005319149
189	35721	6751269	13.7477271	5.7387936	.005291005
190	3	6	1	5.74	.005263158
191	3	6	1	5.7	.005235602
192	3	7	1	5.7	.005208333
193	3	7	1	5.7	.005181347
194	3	7	1	5.7	.005154639
195	3	7	1	5.7	.005128205
196	3	7	1	5.8	.005102041
197	3	7	1	5.8	.005076142
198	3	7	1	5.8	.005050505
199	3	7	1	5.8	.005025126
200	40000	8000000	14.1421356	5.8480355	.005000000
201	40401	8120601	14.1774469	5.8577660	.004975124
202	40804	8242408	14.2126704	5.8674643	.004950495
203	41209	8365427	14.2478068	5.8771307	.004926108
204	41616	8489664	14.2828569	5.8867653	.004901961
205	42025	8615125	14.3178211	5.8963685	.004878049
206	42436	8741816	14.3527001	5.9059406	.004854369
207	42849	8869743	14.3874946	5.9154817	.004830918
208	43264	8998912	14.4222051	5.9249921	.004807692
209	43681	9129329	14.4568323	5.9344721	.004784689
210	44100	9261000		5.9439220	.004761905
211	44521	9393931		5.9533418	.004739336
212	44944	9528128		5.9627320	.004716981
213	45369	9663597		5.9720926	.004694836
214	45796	9800344		5.9814240	.004672897
215	46225	9938375		5.9907264	.004651163
216	46656	10077696		6.0000000	.004629630
217	47089	10218313		6.0092450	.004608295
218	47524	10360232		6.0184617	.004587156
219	47961	10503459		6.0276502	.004566210
220		10648000		6.0368107	.004545455
221		10793861		6.0459435	.004524887
222		10941048		6.0550489	.004504505
223		11089567		6.0641270	.004484305
224		11239424		6.0731779	.004464286
225		11390625		6.0822020	.004444444
226		11543176		6.0911994	.004424779
227		11697083		6.1001702	.004405286
228		11852352		6.1091147	.004385965
229		12008989		6.1180332	.004366812
230	52900	12167000	15.1657509	6.1269257	.004347826
231	53361	12326391	15.1986842	6.1357924	.004329004
232	53824	12487168	15.2315462	6.1446337	.004310345
233	54289	12649337	15.2643375	6.1534495	.004291845
234	54756	12812904	15.2970585	6.1622401	.004273504
235	55225	12977875	15.3297097	6.1710058	.004255319
236	55696	13144256	15.3622915	6.1797466	.004237288
237	56169	13312053	15.3948043	6.1884628	.004219409
238	56644	13481272	15.4272486	6.1971544	.004201681
239	57121	13651919	15.4596248	6.2058218	.004184100
240	57600	13824000	15.4919334	6.2144650	66667
241	58081	13997521	15.5241747	6.2230843	49378
242	58564	14172488	15.5563492	6.2316797	32231
243	59049	14348907	15.5884573	6.2402515	15226
244	59536	14526784	15.6204994	6.2487998	98361
245	60025	14706125	15.6524758	6.2573248	81633
246	60516	14886936	15.6843871	6.2658266	
247	61009	15069223	15.7162336	6.2743054	
248	61504	15252992	15.7480157	6.2827613	

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
249	62001	15438249	15.7797338	6.2911946	.004016064
250	62500	15625000	15.8113883	6.2996053	.004000000
251	63001	15813251	15.8429795	6.3079935	.003984064
252	63504	16003008	15.8745079	6.3163596	.003968254
253	64009	16194277	15.9059737	6.3247035	.003952569
254	64516	16387064	15.9373775	6.3330256	.003937008
255	65025	16581375	15.9687194	6.3413257	.003921569
256	65536	16777216	16.0000000	6.3496042	.003906250
257	66049	16974593	16.0312195	6.3578611	.003891051
258	66564	17173512	16.0623784	6.3660968	.003875969
259	67081	17373979	16.0934769	6.3743111	.003861004
260	67600	17576000	16.1245155	6.3825043	.003846154
261	68121	17779581	16.1554944	6.3906765	.003831418
262	68644	17984728	16.1864141	6.3988279	.003816794
263	69169	18191447	16.2172747	6.4069585	.003802281
264	69696	18399744	16.2480768	6.4150687	.003787879
265	70225	18609625	16.2788206	6.4231583	.003773585
266	70756	18821096	16.3095064	6.4312276	.003759398
267	71289	19034163	16.3401346	6.4392767	.003745318
268	71824	19248832	16.3707055	6.4473057	.003731343
269	72361	19465109	16.4012195	6.4553148	.003717472
270	72900	19683000	16.4316767	6.4633041	.003703704
271	73441	19902511	16.4620776	6.4712736	.003690037
272	73984	20123648	16.4924225	6.4792236	.003676471
273	74529	20346417	16.5227116	6.4871541	.003663004
274	75076	20570824	16.5529454	6.4950653	.003649635
275	75625	20796875	16.5831240	6.5029572	.003636364
276	76176	21024576	16.6132477	6.5108300	.003623188
277	76729	21253933	16.6433170	6.5186839	.003610108
278	77284	21484952	16.6733320	6.5265189	.003597122
279	77841	21717639	16.7032931	6.5343351	.003584229
280	78400	21952000	16.7332005	6.5421326	.003571429
281	78961	22188041	16.7630546	6.5499116	.003558719
282	79524	22425768	16.7928556	6.5576722	.003546099
283	80089	22665187	16.8226038	6.5654144	.003533569
284	80656	22906304	16.8522995	6.5731385	.003521127
285	81225	23149125	16.8819430	6.5808443	.003508772
286	81796	23393656	16.9115345	6.5885323	.003496503
287	82369	23639903	16.9410743	6.5962023	.003484321
288	82944	23887872	16.9705627	6.6038545	.003472222
289	83521	24137569	17.0000000	6.6114890	.003460208
290	84100	24389000	17.0293864	6.6191060	.003448276
291	84681	24642171	17.0587221	6.6267054	.003436426
292	85264	24897088	17.0880075	6.6342874	.003424658
293	85849	25153757	17.1172428	6.6418522	.003412969
294	86436	25412184	17.1464282	6.6493998	.003401361
295	87025	25672375	17.1755640	6.6569302	.003389831
296	87616	25934336	17.2046505	6.6644437	.003378378
297	88209	26198073	17.2336879	6.6719403	.003367003
298	88804	26463592	17.2626765	6.6794200	.003355705
299	89401	26730899	17.2916165	6.6868831	.003344482
300	90000	27000000	17.3205081	6.6943295	.003333333
301	90601	27270901	17.3493516	6.7017593	.003322259
302	91204	27543608	17.3781472	6.7091729	.003311258
303	91809	27818127	17.4068952	6.7165700	.003300330
304	92416	28094464	17.4355958	6.7239508	.003289474
305	93025	28372625	17.4642492	6.7313155	.003278689
306	93636	28652616	17.4928557	6.7386641	.003267974
307	94249	28934443	17.5214155	6.7459967	.003257329
308	94864	29218112	17.5499288	6.7533134	.003246753
309	95481	29503629	17.5783958	6.7606143	.003236246
310	96100	29791000	17.6068169	6.7678995	.003225806

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
311	96721	30080231	17.6351921	6.7751690	.003215434
312	97344	30371328	17.6635217	6.7824229	.003205128
313	97969	30664297	17.6918060	6.7896613	.003194888
314	98596	30959144	17.7200451	6.7968844	.003184713
315	99225	31255875	17.7482393	6.8040921	.003174603
316	99856	31554496	17.7763888	6.8112847	.003164557
317	100489	31855013	17.8044938	6.8184620	.003154574
318	101124	32157432	17.8325545	6.8256242	.003144654
319	101761	32461759	17.8605711	6.8327714	.003134796
320	102400	32768000	17.8885438	6.8399037	.003125000
321	103041	33076161	17.9164729	6.8470213	.003115265
322	103684	33386248	17.9443584	6.8541240	.003105590
323	104329	33698267	17.9722008	6.8612120	.003095975
324	104976	34012224	18.0000000	6.8682855	.003086420
325	105625	34328125	18.0277564	6.8753443	.003076923
326	106276	34645976	18.0554701	6.8823888	.003067485
327	106929	34965783	18.0831413	6.8894188	.003058104
328	107584	35287552	18.1107703	6.8964345	.003048780
329	108241	35611289	18.1383571	6.9034359	.003039514
330	108900	35937000	18.1659021	6.9104232	.003030303
331	109561	36264691	18.1934054	6.9173964	.003021148
332	110224	36594368	18.2208672	6.9243556	.003012048
333	110889	36926037	18.2482876	6.9313008	.003003003
334	111556	37259704	18.2756669	6.9382321	.002994012
335	112225	37595375	18.3030052	6.9451496	.002985075
336	112896	37933056	18.3303028	6.9520533	.002976190
337	113569	38272753	18.3575598	6.9589434	.002967359
338	114244	38614472	18.3847763	6.9658198	.002958580
339	114921	38958219	18.4119526	6.9726826	.002949853
340	115600	39304000	18.4390889	6.9795321	.002941176
341	116281	39651821	18.4661853	6.9863681	.002932551
342	116964	40001688	18.4932420	6.9931906	.002923977
343	117649	40353607	18.5202592	7.0000000	.002915452
344	118336	40707584	18.5472370	7.0067962	.002906977
345	119025	41063625	18.5741756	7.0135791	.002898551
346	119716	41421736	18.6010752	7.0203490	.002890173
347	120409	41781923	18.6279360	7.0271058	.002881844
348	121104	42144192	18.6547581	7.0338497	.002873563
349	121801	42508549	18.6815417	7.0405806	.002865330
350	122500	42875000	18.7082869	7.0472987	.002857143
351	123201	43243551	18.7349940	7.0540041	.002849003
352	123904	43614208	18.7616630	7.0606967	.002840909
353	124609	43986977	18.7882942	7.0673767	.002832861
354	125316	44361864	18.8148877	7.0740440	.002824859
355	126025	44738875	18.8414437	7.0806988	.002816901
356	126736	45118016	18.8679623	7.0873411	.002808989
357	127449	45499293	18.8944436	7.0939709	.002801120
358	128164	45882712	18.9208879	7.1005885	.002793296
359	128881	46268279	18.9472953	7.1071937	.002785515
360	129600	46656000	18.9736660	7.1137866	.002777778
361	130321	47045881	19.0000000	7.1203674	.002770083
362	131044	47437928	19.0262976	7.1269360	.002762431
363	131769	47832147	19.0525589	7.1334925	.002754821
364	132496	48228544	19.0787840	7.1400370	.002747253
365	133225	48627125	19.1049732	7.1465695	.002739726
366	133956	49027896	19.1311265	7.1530901	.002732240
367	134689	49430863	19.1572441	7.1595988	.002724796
368	135424	49836032	19.1833261	7.1660957	.002717391
369	136161	50243409	19.2093727	7.1725809	.002710027
370	136900	50653000	19.2353841	7.1790544	.002702703
371	137641	51064811	19.2613603	7.1855162	.002695418
372	138384	51478848	19.2873015	7.1919663	.002688172

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
373	139129	51895117	19.3132079	7.1984050	.002680965
374	139876	52313624	19.3390796	7.2048322	.002673797
375	140625	52734375	19.3649167	7.2112479	.002666667
376	141376	53157376	19.3907194	7.2176522	.002659574
377	142129	53582633	19.4164878	7.2240450	.002652520
378	142884	54010152	19.4422221	7.2304268	.002645503
379	143641	54439939	19.4679223	7.2367972	.002638522
380	144400	54872000	19.4935887	7.2431565	.002631579
381	145161	55306341	19.5192213	7.2495045	.002624672
382	145924	55742968	19.5448203	7.2558415	.002617801
383	146689	56181887	19.5703858	7.2621675	.002610966
384	147456	56623104	19.5959179	7.2684824	.002604167
385	148225	57066625	19.6214169	7.2747864	.002597403
386	148996	57512456	19.6468827	7.2810794	.002590674
387	149769	57960603	19.6723156	7.2873617	.002583979
388	150544	58411072	19.6977156	7.2936330	.002577320
389	151321	58863869	19.7230829	7.2998936	.002570694
390	152100	59319000	19.7484177	7.3061436	.002564103
391	152881	59776471	19.7737199	7.3123828	.002557545
392	153664	60236288	19.7989899	7.3186114	.002551020
393	154449	60698457	19.8242276	7.3248295	.002544529
394	155236	61162984	19.8494332	7.3310369	.002538071
395	156025	61629875	19.8746069	7.3372339	.002531646
396	156816	62099136	19.8997487	7.3434205	.002525253
397	157609	62570773	19.9248588	7.3495966	.002518892
398	158404	63044792	19.9499373	7.3557624	.002512563
399	159201	63521199	19.9749844	7.3619178	.002506266
400	160000	64000000	20.0000000	7.3680630	.002500000
401	160801	64481201	20.0249844	7.3741979	.002493766
402	161604	64964808	20.0499377	7.3803227	.002487562
403	162409	65450827	20.0748599	7.3864373	.002481390
404	163216	65939264	20.0997512	7.3925418	.002475248
405	164025	66430125	20.1246118	7.3986363	.002469136
406	164836	66923416	20.1494417	7.4047206	.002463054
407	165649	67419143	20.1742410	7.4107950	.002457002
408	166464	67917312	20.1990099	7.4168595	.002450980
409	167281	68417929	20.2237484	7.4229142	.002444988
410	168100	68921000	20.2484567	7.4289589	.002439024
411	168921	69426531	20.2731349	7.4349938	.002433090
412	169744	69934528	20.2977831	7.4410189	.002427184
413	170569	70444997	20.3224014	7.4470342	.002421308
414	171396	70957944	20.3469899	7.4530399	.002415459
415	172225	71473375	20.3715488	7.4590359	.002409639
416	173056	71991296	20.3960781	7.4650223	.002403846
417	173889	72511713	20.4205779	7.4709991	.002398082
418	174724	73034632	20.4450483	7.4769664	.002392344
419	175561	73560059	20.4694895	7.4829242	.002386635
420	176400	74088000	20.4939015	7.4888724	.002380952
421	177241	74618461	20.5182845	7.4948113	.002375297
422	178084	75151448	20.5426386	7.5007406	.002369668
423	178929	75686967	20.5669638	7.5066607	.002364066
424	179776	76225024	20 5912603	7.5125715	.002358491
425	180625	76765625	20.6155281	7.5184730	.002352941
426	181476	77308776	20.6397674	7.5243652	.002347418
427	182329	77854483	20.6639783	7.5302482	.002341920
428	183184	78402752	20.6881609	7.5361221	.002336449
429	184041	78953589	20.7123152	7.5419867	.002331002
430	184900	79507000	20.7364414	7.5478423	.002325581
431	185761	80062991	20.7605395	7.5536888	.002320186
432	186624	80621568	20.7846097	7.5595263	.002314815
433	187489	81182737	20.8086520	7.5653548	.002309469
434	188356	81746504	20.8326667	7.5711743	.002304147

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
435	189225	82312875	20.8566536	7.5770849	.002298851
436	190096	82881856	20.8806130	7.5828865	.002293578
437	190969	83453453	20.9045450	7.5886793	.002288330
438	191844	84027672	20.9284495	7.5944633	.002283105
439	192721	84604519	20.9523268	7.6002386	.002277904
440	193600	85184000	20.9761770	7.6060049	.002272727
441	194481	85766121	21.0000000	7.6117626	.002267574
442	195364	86350888	21.0237960	7.6174116	.002262443
443	196249	86938307	21.0475652	7.6231519	.002257336
444	197136	87528384	21.0713075	7.6288837	.002252252
445	198025	88121125	21.0950231	7.6346067	.002247191
446	198916	88716536	21.1187121	7.6403213	.002242152
447	199809	89314623	21.1423745	7.6460272	.002237136
448	200704	89915392	21.1660105	7.6517247	.002232143
449	201601	90518849	21.1896201	7.6574138	.002227171
450	202500	91125000	21.2132034	7.6630943	.002222222
451	203401	91733851	21.2367606	7.6687665	.002217295
452	204304	92345408	21.2602916	7.6744303	.002212389
453	205209	92959677	21.2837967	7.6800857	.002207506
454	206116	93576664	21.3072758	7.6857328	.002202643
455	207025	94196375	21.3307290	7.6913717	.002197802
456	207936	94818816	21.3541565	7.6970023	.002192982
457	208849	95443993	21.3775583	7.7026246	.002188184
458	209764	96071912	21.4009346	7.7082388	.002183406
459	210681	96702579	21.4242853	7.7138448	.002178649
460	211600	97336000	21.4476106	7.7194426	.002173913
461	212521	97972181	21.4709106	7.7250325	.002169197
462	213444	98611128	21.4941853	7.7306141	.002164502
463	214369	99252847	21.5174348	7.7361877	.002159827
464	215296	99897344	21.5406592	7.7417532	.002155172
465	216225	100544625	21.5638587	7.7473109	.002150538
466	217156	101194696	21.5870331	7.7528606	.002145923
467	218089	101847563	21.6101828	7.7584023	.002141328
468	219024	102503232	21.6333077	7.7639361	.002136752
469	219961	103161709	21.6564078	7.7694620	.002132196
470	220900	103823000	21.6794834	7.7749801	.002127660
471	221841	104487111	21.7025344	7.7804904	.002123142
472	222784	105154048	21.7255610	7.7859928	.002118644
473	223729	105823817	21.7485632	7.7914875	.002114165
474	224676	106496424	21.7715411	7.7969745	.002109705
475	225625	107171875	21.7944947	7.8024538	.002105263
476	226576	107850176	21.8174242	7.8079254	.002100840
477	227529	108531333	21.8403297	7.8133892	.002096436
478	228484	109215352	21.8632111	7.8188456	.002092050
479	229441	109902239	21.8860686	7.8242942	.002087683
480	230400	110592000	21.9089023	7.8297353	.002083333
481	231361	111284641	21.9317122	7.8351688	.002079002
482	232324	111980168	21.9544984	7.8405949	.002074689
483	233289	112678587	21.9772610	7.8460134	.002070393
484	234256	113379904	22.0000000	7.8514244	.002066116
485	235225	114084125	22.0227155	7.8568281	.002061856
486	236196	114791256	22.0454077	7.8622242	.002057613
487	237169	115501303	22.0680765	7.8676130	.002053388
488	238144	116214272	22.0907220	7.8729944	.002049180
489	239121	116930169	22.1133444	7.8783684	.002044990
490	240100	117649000	22.1359436	7.8837352	.002040816
491	241081	118370771	22.1585198	7.8890946	.002036660
492	242064	119095488	22.1810730	7.8944468	.002032520
493	243049	119823157	22.2036033	7.8997917	.002028398
494	244036	120553784	22.2261108	7.9051294	.002024291
495	245025	121287375	22.2485955	7.9104599	.002020202
496	246016	122023936	22.2710575	7.9157832	.002016129

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
497	247009	122763473	22.2934968	7.9210994	.002012072
498	248004	123505992	22.3159136	7.9264085	.002008032
499	249001	124251499	22.3383079	7.9317104	.002004008
500	250000	125000000	22.3606798	7.9370053	.002000000
501	251001	125751501	22.3830293	7.9422931	.001996008
502	252004	126506008	22.4053565	7.9475739	.001992032
503	253009	127263527	22.4276615	7.9528477	.001988072
504	254016	128024064	22.4499443	7.9581144	.001984127
505	255025	128787625	22.4722051	7.9633743	.001980198
506	256036	129554216	22.4944438	7.9686271	.001976285
507	257049	130323843	22.5166605	7.9738731	.001972387
508	258064	131096512	22.5388553	7.9791122	.001968504
509	259081	131872229	22.5610283	7.9843444	.001964637
510	260100	132651000	22.5831796	7.9895697	.001960784
511	261121	133432831	22.6053091	7.9947883	.001956947
512	262144	134217728	22.6274170	8.0000000	.001953125
513	263169	135005697	22.6495033	8.0052049	.001949318
514	264196	135796744	22.6715681	8.0104032	.001945525
515	265225	136590875	22.6936114	8.0155946	.001941748
516	266256	137388096	22.7156334	8.0207794	.001937984
517	267289	138188413	22.7376340	8.0259574	.001934236
518	268324	138991832	22.7596134	8.0311287	.001930502
519	269361	139798359	22.7815715	8.0362935	.001926782
520	270400	140608000	22.8035085	8.0414515	.001923077
521	271441	141420761	22.8254244	8.0466030	.001919386
522	272484	142236648	22.8473193	8.0517479	.001915709
523	273529	143055667	22.8691933	8.0568862	.001912046
524	274576	143877824	22.8910463	8.0620180	.001908397
525	275625	144703125	22.9128785	8.0671432	.001904762
526	276676	145531576	22.9346899	8.0722620	.001901141
527	277729	146363183	22.9564806	8.0773743	.001897533
528	278784	147197952	22.9782506	8.0824800	.001893939
529	279841	148035889	23.0000000	8.0875794	.001890359
530	280900	148877000	23.0217289	8.0926723	.001886792
531	281961	149721291	23.0434372	8.0977589	.001883239
532	283024	150568768	23.0651252	8.1028390	.001879699
533	284089	151419437	23.0867928	8.1079128	.001876173
534	285156	152273304	23.1084400	8.1129803	.001872659
535	286225	153130375	23.1300670	8.1180414	.001869159
536	287296	153990656	23.1516738	8.1230962	.001865672
537	288369	154854153	23.1732605	8.1281447	.001862197
538	289444	155720872	23.1948270	8.1331870	.001858736
539	290521	156590819	23.2163735	8.1382230	.001855288
540	291600	157464000	23.2379001	8.1432529	.001851852
541	292681	158340421	23.2594067	8.1482765	.001848429
542	293764	159220088	23.2808935	8.1532939	.001845018
543	294849	160103007	23.3023604	8.1583051	.001841621
544	295936	160989184	23.3238076	8.1633102	.001838235
545	297025	161878625	23.3452351	8.1683092	.001834862
546	298116	162771336	23.3666429	8.1733020	.001831502
547	299209	163667323	23.3880311	8.1782888	.001828154
548	300304	164566592	23.4093998	8.1832695	.001824818
549	301401	165469149	23.4307490	8.1882441	.001821494
550	302500	166375000	23.4520788	8.1932127	.001818182
551	303601	167284151	23.4733892	8.1981753	.001814882
552	304704	168196608	23.4946802	8.2031319	.001811594
553	305809	169112377	23.5159520	8.2080825	.001808318
554	306916	170031464	23.5372046	8.2130271	.001805054
555	308025	170953875	23.5584380	8.2179657	.001801802
556	309136	171879616	23.5796522	8.2228985	.001798561
557	310249	172808693	23.6008474	8.2278254	.001795332
558	311364	173741112	23.6220236	8.2327463	.001792115

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
559	312481	174676879	23.6431808	8.2376614	.001788909
560	313600	175616000	23.6643191	8.2425706	.001785714
561	314721	176558481	23.6854386	8.2474740	.001782531
562	315844	177504328	23.7065392	8.2523715	.001779359
563	316969	178453547	23.7276210	8.2572633	.001776199
564	318096	179406144	23.7486842	8.2621492	.001773050
565	319225	180362125	23.7697286	8.2670294	.001769912
566	320356	181321496	23.7907545	8.2719039	.001766784
567	321489	182284263	23.8117618	8.2767726	.001763668
568	322624	183250432	23.8327506	8.2816355	.001760563
569	323761	184220000	23.8537209	8.2864928	.001757469
570	324900	185193000	23.8746728	8.2913444	.001754386
571	326041	186169411	23.8956063	8.2961903	.001751313
572	327184	187149248	23.9165215	8.3010304	.001748252
573	328329	188132517	23.9374184	8.3058651	.001745201
574	329476	189119224	23.9582971	8.3106941	.001742160
575	330625	190109375	23.9791576	8.3155175	.001739130
576	331776	191102976	24.0000000	8.3203353	.001736111
577	332929	192100033	24.0208243	8.3251475	.001733102
578	334084	193100552	24.0416306	8.3299542	.001730104
579	335241	194104539	24.0624188	8.3347553	.001727116
580	336400	195112000	24.0831891	8.3395509	.001724138
581	337561	196122941	24.1039416	8.3443410	.001721170
582	338724	197137368	24.1246762	8.3491256	.001718213
583	339889	198155287	24.1453929	8.3539047	.001715266
584	341056	199176704	24.1660919	8.3586784	.001712329
585	342225	200201625	24.1867732	8.3634466	.001709402
586	343396	201230056	24.2074369	8.3682095	.001706485
587	344569	202262003	24.2280829	8.3729668	.001703578
588	345744	203297472	24.2487113	8.3777188	001700680
589	346921	204336469	24.2693222	8.3824653	001697793
590	348100	205379000	24.2899156	8.3872065	.001694915
591	349281	206425071	24.3104916	8.3919423	.001692047
592	350464	207474688	24.3310501	8.3966729	.001689189
593	351649	208527857	24.3515913	8.4013981	.001686341
594	352836	209584584	24.3721152	8.4061180	.001683502
595	354025	210644875	24.3926218	8.4108326	.001680672
596	355216	211708736	24.4131112	8.4155419	.001677852
597	356409	212776173	24.4335834	8.4202460	.001675042
598	357604	213847192	24.4540385	8.4249448	.001672241
599	358801	214921799	24.4744765	8.4296383	.001669449
600	360000	216000000	24.4948974	8.4343267	.001666667
601	361201	217081801	24.5153013	8.4390098	.001663894
602	362404	218167208	24.5356883	8.4436877	.001661130
603	363609	219256227	24.5560583	8.4483605	.001658375
604	364816	220348864	24.5764115	8.4530281	.001655629
605	366025	221445125	24.5967478	8.4576906	.001652893
606	367236	222545016	24.6170673	8.4623479	.001650165
607	368449	223648543	24.6373700	8.4670001	.001647446
608	369664	224755712	24.6576560	8.4716471	.001644737
609	370881	225866529	24.6779254	8.4762892	.001642036
610	372100	226981000	24.6981781	8.4809261	.001639344
611	373321	228099131	24.7184142	8.4855579	.001636661
612	374544	229220928	24.7386338	8.4901848	.001633987
613	375769	230346397	24.7588368	8.4948065	.001631321
614	376996	231475544	24.7790234	8.4994233	.001628664
615	378225	232608375	24.7991935	8.5040350	.001626016
616	379456	233744896	24.8193473	8.5086417	.001623377
617	380689	234885113	24.8394847	8.5132435	.001620746
618	381924	236029032	24.8596058	8.5178403	.001618123
619	383161	237176659	24.8797106	8.5224321	.001615509
620	384400	238328000	24.8997992	8.5270189	.001612903

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. *(Continued.)*

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
621	385641	239483061	24.9198716	8.5316009	.001610306
622	386884	240641848	24.9399278	8.5361780	.001607717
623	388129	241804367	24.9599679	8.5407501	.001605136
624	389376	242970624	24.9799920	8.5453173	.001602564
625	390625	244140625	25.0000000	8.5498797	.001600000
626	391876	245314376	25.0199920	8.5544372	.001597444
627	393129	246491883	25.0399681	8.5589899	.001594896
628	394384	247673152	25.0599282	8.5635377	.001592357
629	395641	248858189	25.0798724	8.5680807	.001589825
630	396900	250047000	25.0998008	8.5726189	.001587302
631	398161	251239591	25.1197134	8.5771523	.001584786
632	399424	252435968	25.1396102	8.5816809	.001582278
633	400689	253636137	25.1594913	8.5862047	.001579779
634	401956	254840104	25.1793566	8.5907238	.001577287
635	403225	256047875	25.1992063	8.5952380	.001574803
636	404496	257259456	25.2190404	8.5997476	.001572327
637	405769	258474853	25.2388589	8.6042525	.001569859
638	407044	259694072	25.2586619	8.6087526	.001567398
639	408321	260917119	25.2784493	8.6132480	.001564945
640	409600	262144000	25.2982213	8.6177388	.001562500
641	410881	263374721	25.3179778	8.6222248	.001560062
642	412164	264609288	25.3377189	8.6267063	.001557632
643	413449	265847707	25.3574447	8.6311830	.001555210
644	414736	267089984	25.3771551	8.6356551	.001552795
645	416025	268336125	25.3968502	8.6401226	.001550388
646	417316	269586136	25.4165301	8.6445855	.001547988
647	418609	270840023	25.4361947	8.6490437	.001545595
648	419904	272097792	25.4558441	8.6534974	.001543210
649	421201	273359449	25.4754784	8.6579465	.001540832
650	422500	274625000	25.4950976	8.6623911	.001538462
651	423801	275894451	25.5147016	8.6668310	.001536098
652	425104	277167808	25.5342907	8.6712665	.001533742
653	426409	278445077	25.5538647	8.6756974	.001531394
654	427716	279726264	25.5734237	8.6801237	.001529052
655	429025	281011375	25.5929678	8.6845456	.001526718
656	430336	282300416	25.6124969	8.6889630	.001524390
657	431649	283593393	25.6320112	8.6933759	.001522070
658	432964	284890312	25.6515107	8.6977843	.001519757
659	434281	286191179	25.6709953	8.7021882	.001517451
660	435600	287496000	25.6904652	8.7065877	.001515152
661	436921	288804781	25.7099203	8.7109827	.001512859
662	438244	290117528	25.7293607	8.7153734	.001510574
663	439569	291434247	25.7487864	8.7197596	.001508296
664	440896	292754944	25.7681975	8.7241414	.001506024
665	442225	294079625	25.7875939	8.7285187	.001503759
666	443556	295408296	25.8069758	8.7328918	.001501502
667	444889	296740963	25.8263431	8.7372604	.001499250
668	446224	298077632	25.8456960	8.7416246	.001497006
669	447561	299418309	25.8650343	8.7459846	.001494768
670	448900	300763000	25.8843582	8.7503401	.001492537
671	450241	302111711	25.9036677	8.7546913	.001490313
672	451584	303464448	25.9229628	8.7590383	.001488095
673	452929	304821217	25.9422435	8.7633809	.001485884
674	454276	306182024	25.9615100	8.7677192	.001483680
675	455625	307546875	25.9807621	8.7720532	.001481481
676	456976	308915776	26.0000000	8.7763830	.001479290
677	458329	310288733	26.0192237	8.7807084	.001477105
678	459684	311665752	26.0384331	8.7850296	.001474926
679	461041	313046839	26.0576284	8.7893466	.001472754
680	462400	314432000	26.0768096	8.7936593	.001470588
681	463761	315821241	26.0959767	8.7979679	.001468429
682	465124	317214568	26.1151297	8.8022721	.001466276

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
683	466489	318611987	26.1342687	8.8065722	.001464129
684	467856	320013504	26.1533937	8.8108681	.001461988
685	469225	321419125	26.1725047	8.8151598	.001459854
686	470596	322828856	26.1916017	8.8194474	.001457726
687	471969	324242703	26.2106848	8.8237307	.001455604
688	473344	325660672	26.2297541	8.8280099	.001453488
689	474721	327082769	26.2488095	8.8322850	.001451379
690	476100	328509000	26.2678511	8.8365559	.001449275
691	477481	329939371	26.2868789	8.8408227	.001447178
692	478864	331373888	26.3058929	8.8450854	.001445087
693	480249	332812557	26.3248932	8.8493440	.001443001
694	481636	334255384	26.3438797	8.8535985	.001440922
695	483025	335702375	26.3628527	8.8578489	.001438849
696	484416	337153536	26.3818119	8.8620952	.001436782
697	485809	338608873	26.4007576	8.8663375	.001434720
698	487204	340068392	26.4196896	8.8705757	.001432665
699	488601	341532099	26.4386081	8.8748099	.001430615
700	490000	343000000	26.4575131	8.8790400	.001428571
701	491401	344472101	26.4764046	8.8832661	.001426534
702	492804	345948408	26.4952826	8.8874882	.001424501
703	494209	347428927	26.5141472	8.8917063	.001422475
704	495616	348913664	26.5329983	8.8959204	.001420455
705	497025	350402625	26.5518361	8.9001304	.001418440
706	498436	351895816	26.5706605	8.9043366	.001416431
707	499849	353393243	26.5894716	8.9085387	.001414427
708	501264	354894912	26.6082694	8.9127369	.001412429
709	502681	356400829	26.6270539	8.9169311	.001410437
710	504100	357911000	26.6458252	8.9211214	.001408451
711	505521	359425431	26.6645833	8.9253078	.001406470
712	506944	360944128	26.6833281	8.9294902	.001404494
713	508369	362467097	26.7020598	8.9336687	.001402525
714	509796	363994344	26.7207784	8.9378433	.001400560
715	511225	365525875	26.7394839	8.9420140	.001398601
716	512656	367061696	26.7581763	8.9461809	.001396648
717	514089	368601813	26.7768557	8.9503438	.001394700
718	515524	370146232	26.7955220	8.9545029	.001392758
719	516961	371694959	26.8141754	8.9586581	.001390821
720	518400	373248000	26.8328157	8.9628095	.001388889
721	519841	374805361	26.8514432	8.9669570	.001386963
722	521284	376367048	26.8700577	8.9711007	.001385042
723	522729	377933067	26.8886593	8.9752406	.001383126
724	524176	379503424	26.9072481	8.9793766	.001381215
725	525625	381078125	26.9258240	8.9835089	.001379310
726	527076	382657176	26.9443872	8.9876373	.001377410
727	528529	384240583	26.9629375	8.9917620	.001375516
728	529984	385828352	26.9814751	8.9958829	.001373626
729	531441	387420489	27.0000000	9.0000000	.001371742
730	532900	389017000	27.0185122	9.0041134	.001369863
731	534361	390617891	27.0370117	9.0082229	.001367989
732	535824	392223168	27.0554985	9.0123288	.001366120
733	537289	393832837	27.0739727	9.0164309	.001364256
734	538756	395446904	27.0924344	9.0205293	.001362398
735	540225	397065375	27.1108834	9.0246239	.001360544
736	541696	398688256	27.1293199	9.0287149	.001358696
737	543169	400315553	27.1477439	9.0328021	.001356852
738	544644	401947272	27.1661554	9.0368857	.001355014
739	546121	403583419	27.1845544	9.0409655	.001353180
740	547600	405224000	27.2029410	9.0450419	.001351351
741	549081	406869021	27.2213152	9.0491142	.001349528
742	550564	408518488	27.2396769	9.0531831	.001347709
743	552049	410172407	27.2580263	9.0572482	.001345895
744	553536	411830784	27.2763634	9.0613098	.001344086

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
745	555025	413493625	27.2946881	9.0653677	.001342282
746	556516	415160936	27.3130006	9.0694220	.001340483
747	558009	416832723	27.3313007	9.0734726	.001338688
748	559504	418508992	27.3495887	9.0775197	.001336898
749	561001	420189749	27.3678644	9.0815631	.001335113
750	562500	421875000	27.3861279	9.0856030	.001333333
751	564001	423564751	27.4043792	9.0896392	.001331558
752	565504	425259008	27.4226184	9.0936719	.001329787
753	567009	426957777	27.4408455	9.0977010	.001328021
754	568516	428661064	27.4590604	9.1017265	.001326260
755	570025	430368875	27.4772632	9.1057485	.001324503
756	571536	432081216	27.4954542	9.1097669	.001322751
757	573049	433798093	27.5136330	9.1137818	.001321004
758	574564	435519512	27.5317998	9.1177931	.001319261
759	576081	437245479	27.5499546	9.1218010	.001317523
760	577600	438976000	27.5680975	9.1258053	.001315789
761	579121	440711081	27.5862284	9.1298061	.001314060
762	580644	442450728	27.6043475	9.1338034	.001312336
763	582169	444194947	27.6224546	9.1377971	.001310616
764	583696	445943744	27.6405499	9.1417874	.001308901
765	585225	447697125	27.6586334	9.1457742	.001307190
766	586756	449455096	27.6767050	9.1497576	.001305483
767	588289	451217663	27.6947648	9.1537375	.001303781
768	589824	452984832	27.7128129	9.1577139	.001302083
769	591361	454756609	27.7308492	9.1616869	.001300390
770	592900	456533000	27.7488739	9.1656565	.001298701
771	594441	458314011	27.7668868	9.1696225	.001297017
772	595984	460099648	27.7848880	9.1735852	.001295337
773	597529	461889917	27.8028775	9.1775445	.001293661
774	599076	463684824	27.8208555	9.1815003	.001291990
775	600625	465484375	27.8388218	9.1854527	.001290323
776	602176	467288576	27.8567766	9.1894018	.001288660
777	603729	469097433	27.8747197	9.1933474	.001287001
778	605284	470910952	27.8926514	9.1972897	.001285347
779	606841	472729139	27.9105715	9.2012286	.001283697
780	608400	474552000	27.9284801	9.2051641	.001282051
781	609961	476379541	27.9463772	9.2090962	.001280410
782	611524	478211768	27.9642629	9.2130250	.001278772
783	613089	480048687	27.9821372	9.2169505	.001277139
784	614656	481890304	28.0000000	9.2208726	.001275510
785	616225	483736625	28.0178515	9.2247914	.001273885
786	617796	485587656	28.0356915	9.2287068	.001272265
787	619369	487443403	28.0535203	9.2326189	.001270648
788	620944	489303872	28.0713377	9.2365277	.001269036
789	622521	491169069	28.0891438	9.2404333	.001267427
790	624100	493039000	28.1069386	9.2443355	.001265823
791	625681	494913671	28.1247222	9.2482344	.001264223
792	627264	496793088	28.1424946	9.2521300	.001262626
793	628849	498677257	28.1602557	9.2560224	.001261034
794	630436	500566184	28.1780056	9.2599114	.001259446
795	632025	502459875	28.1957444	9.2637973	.001257862
796	633616	504358336	28.2134720	9.2676798	.001256281
797	635209	506261573	28.2311884	9.2715592	.001254705
798	636804	508169592	28.2488938	9.2754352	.001253133
799	638401	510082399	28.2665881	9.2793081	.001251564
800	640000	512000000	28.2842712	9.2831777	.001250000
801	641601	513922401	28.3019434	9.2870440	.001248439
802	643204	515849608	28.3196045	9.2909072	.001246883
803	644809	517781627	28.3372546	9.2947671	.001245330
804	646416	519718464	28.3548938	9.2986239	.001243781
805	648025	521660125	28.3725219	9.3024775	.001242236
806	649636	523606616	28.3901391	9.3063278	.001240695

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
807	651249	525557943	28.4077454	9.3101750	.001239157
808	652864	527514112	28.4253408	9.3140190	.001237624
809	654481	529475129	28.4429253	9.3178599	.001236094
810	656100	531441000	28.4604989	9.3216975	.001234568
811	657721	533411731	28.4780617	9.3255320	.001233046
812	659344	535387328	28.4956137	9.3293634	.001231527
813	660969	537367797	28.5131549	9.3331916	.001230012
814	662596	539353144	28.5306852	9.3370167	.001228501
815	664225	541343375	28.5482048	9.3408386	.001226994
816	665856	543338496	28.5657137	9.3446575	.001225490
817	667489	545338513	28.5832119	9.3484731	.001223990
818	669124	547343432	28.6006993	9.3522857	.001222494
819	670761	549353259	28.6181760	9.3560952	.001221001
820	672400	551368000	28.6356421	9.3599016	.001219512
821	674041	553387661	28.6530976	9.3637049	.001218027
822	675684	555412248	28.6705424	9.3675051	.001216545
823	677329	557441767	28.6879766	9.3713022	.001215067
824	678976	559476224	28.7054002	9.3750963	.001213592
825	680625	561515625	28.7228132	9.3788873	.001212121
826	682276	563559976	28.7402157	9.3826752	.001210654
827	683929	565609283	28.7576077	9.3864600	.001209190
828	685584	567663552	28.7749891	9.3902419	.001207729
829	687241	569722789	28.7923601	9.3940206	.001206273
830	688900	571787000	28.8097206	9.3977964	.001204819
831	690561	573856191	28.8270706	9.4015691	.001203369
832	692224	575930368	28.8444102	9.4053387	.001201923
833	693889	578009537	28.8617394	9.4091054	.001200480
834	695556	580093704	28.8790582	9.4128690	.001199041
835	697225	582182875	28.8963666	9.4166297	.001197605
836	698896	584277056	28.9136646	9.4203873	.001196172
837	700569	586376253	28.9309523	9.4241420	.001194743
838	702244	588480472	28.9482297	9.4278936	.001193317
839	703921	590589719	28.9654967	9.4316423	.001191895
840	705600	592704000	28.9827535	9.4353880	.001190476
841	707281	594823321	29.0000000	9.4391307	.001189061
842	708964	596947688	29.0172363	9.4428704	.001187648
843	710649	599077107	29.0344623	9.4466072	.001186240
844	712336	601211584	29.0516781	9.4503410	.001184834
845	714025	603351125	29.0688837	9.4540719	.001183432
846	715716	605495736	29.0860791	9.4577999	.001182033
847	717409	607645423	29.1032644	9.4615249	.001180638
848	719104	609800192	29.1204396	9.4652470	.001179245
849	720801	611960049	29.1376046	9.4689661	.001177856
850	722500	614125000	29.1547595	9.4726824	.001176471
851	724201	616295051	29.1719043	9.4763957	.001175088
852	725904	618470208	29.1890390	9.4801061	.001173709
853	727609	620650477	29.2061637	9.4838136	.001172333
854	729316	622835864	29.2232784	9.4875182	.001170960
855	731025	625026375	29.2403830	9.4912200	.001169591
856	732736	627222016	29.2574777	9.4949188	.001168224
857	734449	629422793	29.2745623	9.4986147	.001166861
858	736164	631628712	29.2916370	9.5023078	.001165501
859	737881	633839779	29.3087018	9.5059980	.001164144
860	739600	636056000	29.3257566	9.5096854	.001162791
861	741321	638277381	29.3428015	9.5133699	.001161440
862	743044	640503928	29.3598365	9.5170515	.001160093
863	744769	642735647	29.3768616	9.5207303	.001158749
864	746496	644972544	29.3938769	9.5244063	.001157407
865	748225	647214625	29.4108823	9.5280794	.001156069
866	749956	649461896	29.4278779	9.5317497	.001154734
867	751689	651714363	29.4448637	9.5354172	.001153403
868	753424	653972032	29.4618397	9.5390818	.001152074

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
869	755161	656234909	29.4788059	9.5427437	.001150748
870	756900	658503000	29.4957624	9.5464027	.001149425
871	758641	660776311	29.5127091	9.5500589	.001148106
872	760384	663054848	29.5296461	9.5537123	.001146789
873	762129	665338617	29.5465734	9.5573630	.001145475
874	763876	667627624	29.5634910	9.5610108	.001144165
875	765625	669921875	29.5803989	9.5646559	.001142857
876	767376	672221376	29.5972972	9.5682982	.001141553
877	769129	674526133	29.6141858	9.5719377	.001140251
878	770884	676836152	29.6310648	9.5755745	.001138952
879	772641	679151439	29.6479342	9.5792085	.001137656
880	774400	681472000	29.6647939	9.5828397	.001136364
881	776161	683797841	29.6816442	9.5864682	.001135074
882	777924	686128968	29.6984848	9.5900939	.001133787
883	779689	688465387	29.7153159	9.5937169	.001132503
884	781456	690807104	29.7321375	9.5973373	.001131222
885	783225	693154125	29.7489496	9.6009548	.001129944
886	784996	695506456	29.7657521	9.6045696	.001128668
887	786769	697864103	29.7825452	9.6081817	.001127396
888	788544	700227072	29.7993289	9.6117911	.001126126
889	790321	702595369	29.8161030	9.6153977	.001124859
890	792100	704969000	29.8328678	9.6190017	.001123596
891	793881	707347971	29.8496231	9.6226030	.001122334
892	795664	709732288	29.8663690	9.6262016	.001121076
893	797449	712121957	29.8831056	9.6297975	.001119821
894	799236	714516984	29.8998328	9.6333907	.001118568
895	801025	716917375	29.9165506	9.6369812	.001117318
896	802816	719323136	29.9332591	9.6405690	.001116071
897	804609	721734273	29.9499583	9.6441542	.001114827
898	806404	724150792	29.9666481	9.6477367	.001113586
899	808201	726572699	29.9833287	9.6513166	.001112347
900	810000	729000000	30.0000000	9.6548938	.001111111
901	811801	731432701	30.0166620	9.6584684	.001109878
902	813604	733870808	30.0333148	9.6620403	.001108647
903	815409	736314327	30.0499584	9.6656096	.001107420
904	817216	738763264	30.0665928	9.6691762	.001106195
905	819025	741217625	30.0832179	9.6727403	.001104972
906	820836	743677416	30.0998339	9.6763017	.001103753
907	822649	746142643	30.1164407	9.6798604	.001102536
908	824464	748613312	30.1330383	9.6834166	.001101322
909	826281	751089429	30.1496269	9.6869701	.001100110
910	828100	753571000	30.1662063	9.6905211	.001098901
911	829921	756058031	30.1827765	9.6940694	.001097695
912	831744	758550528	30.1993377	9.6976151	.001096491
913	833569	761048497	30.2158899	9.7011583	.001095290
914	835396	763551944	30.2324329	9.7046989	.001094092
915	837225	766060875	30.2489669	9.7082369	.001092896
916	839056	768575296	30.2654919	9.7117723	.001091703
917	840889	771095213	30.2820079	9.7153051	.001090513
918	842724	773620632	30.2985148	9.7188354	.001089325
919	844561	776151559	30.3150128	9.7223631	.001088139
920	846400	778688000	30.3315018	9.7258883	.001086957
921	848241	781229961	30.3479818	9.7294109	.001085776
922	850084	783777448	30.3644529	9.7329309	.001084599
923	851929	786330467	30.3809151	9.7364484	001083423
924	853776	788889024	30.3973683	9.7399634	.001082251
925	855625	791453125	30.4138127	9.7434758	.001081081
926	857476	794022776	30.4302481	9.7469857	.001079914
927	859329	796597983	30.4466747	9.7504930	.001078749
928	861184	799178752	30.4630924	9.7539979	.001077586
929	863041	801765089	30.4795013	9.7575002	.001076426
[illegible]	864900	804357000	30.4959014	9.7610001	.001075269

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
931	866761	806954491	30.5122926	9.7644974	.001074114
932	868624	809557568	30.5286750	9.7679922	.001072961
933	870489	812166237	30.5450487	9.7714845	.001071811
934	872356	814780504	30.5614136	9.7749743	.001070664
935	874225	817400375	30.5777697	9.7784616	.001069519
936	876096	820025856	30.5941171	9.7819466	.001068376
937	877969	822656953	30.6104557	9.7854288	.001067236
938	879844	825293672	30.6267857	9.7889087	.001066098
939	881721	827936019	30.6431069	9.7923861	.001064963
940	883600	830584000	30.6594194	9.7958611	.001063830
941	885481	833237621	30.6757233	9.7993336	.001062699
942	887364	835896888	30.6920185	9.8028036	.001061571
943	889249	838561807	30.7083051	9.8062711	.001060445
944	891136	841232384	30.7245830	9.8097362	.001059322
945	893025	843908625	30.7408523	9.8131989	.001058201
946	894916	846590536	30.7571130	9.8166591	.001057082
947	896809	849278123	30.7733651	9.8201169	.001055966
948	898704	851971392	30.7896086	9.8235723	.001054852
949	900601	854670349	30.8058436	9.8270252	.001053741
950	902500	857375000	30.8220700	9.8304757	.001052632
951	904401	860085351	30.8382879	9.8339238	.001051525
952	906304	862801408	30.8544972	9.8373695	.001050420
953	908209	865523177	30.8706981	9.8408127	.001049318
954	910116	868250664	30.8868904	9.8442536	.001048218
955	912025	870983875	30.9030743	9.8476920	.001047120
956	913936	873722816	30.9192497	9.8511280	.001046025
957	915849	876467493	30.9354166	9.8545617	.001044932
958	917764	879217912	30.9515751	9.8579929	.001043841
959	919681	881974079	30.9677251	9.8614218	.001042753
960	921600	884736000	30.9838668	9.8648483	.001041667
961	923521	887503681	31.0000000	9.8682724	.001040583
962	925444	890277128	31.0161248	9.8716941	.001039501
963	927369	893056347	31.0322413	9.8751135	.001038422
964	929296	895841344	31.0483494	9.8785305	.001037344
965	931225	898632125	31.0644491	9.8819451	.001036269
966	933156	901428696	31.0805405	9.8853574	.001035197
967	935089	904231063	31.0966236	9.8887673	.001034126
968	937024	907039232	31.1126984	9.8921749	.001033058
969	938961	909853209	31.1287648	9.8955801	.001031992
970	940900	912673000	31.1448230	9.8989830	.001030928
971	942841	915498611	31.1608729	9.9023835	.001029866
972	944784	918330048	31.1769145	9.9057817	.001028807
973	946729	921167317	31.1929479	9.9091776	.001027749
974	948676	924010424	31.2089731	9.9125712	.001026694
975	950625	926859375	31.2249900	9.9159624	.001025641
976	952576	929714176	31.2409987	9.9193513	.001024590
977	954529	932574833	31.2569992	9.9227379	.001023541
978	956484	935441352	31.2729915	9.9261222	.001022495
979	958441	938313739	31.2889757	9.9295042	.001021450
980	960400	941192000	31.3049517	9.9328839	.001020408
981	962361	944076141	31.3209195	9.9362613	.001019368
982	964324	946966168	31.3368792	9.9396363	.001018330
983	966289	949862087	31.3528308	9.9430092	.001017294
984	968256	952763904	31.3687743	9.9463797	.001016260
985	970225	955671625	31.3847097	9.9497479	.001015228
986	972196	958585256	31.4006369	9.9531138	.001014199
987	974169	961504803	31.4165561	9.9564775	.001013171
988	976144	964430272	31.4324673	9.9598389	.001012146
989	978121	967361669	31.4483704	9.9631981	.001011122
990	980100	970299000	31.4642654	9.9665549	.001010101
991	982081	973242271	31.4801525	9.9699095	.001009082
992	984064	976191488	31.4960315	9.9732619	.001008065

SQUARE ROOTS AND CUBE ROOTS OF NUMBERS. (*Continued.*)

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
993	986049	979146657	31.5119025	9.9766120	.001007049
994	988036	982107784	31.5277655	9.9799599	.001006036
995	990025	985074875	31.5436206	9.9833055	.001005025
996	992016	988047936	31.5594677	9.9866488	.001004016
997	994009	991026973	31.5753068	9.9899900	.001003009
998	996004	994011992	31.5911380	9.9933289	.001002004
999	998001	997002999	31.6069613	9.9966656	.001001001
1000	1000000	1000000000	31.6227766	10.0000000	.001000000
1001	1002001	1003003001	31.6385840	10.0033322	.0009990010
1002	1004004	1006012008	31.6543836	10.0066622	.0009980040
1003	1006009	1009027027	31.6701752	10.0099899	.0009970090
1004	1008016	1012048064	31.6859590	10.0133155	.0009960159
1005	1010025	1015075125	31.7017349	10.0166389	.0009950249
1006	1012036	1018108216	31.7175030	10 0199601	.0009940358
1007	1014049	1021147343	31.7332633	10.0232791	.0009930487
1008	1016064	1024192512	31.7490157	10.0265958	.0009920635
1009	1018081	1027243729	31.7647603	10.0299104	.0009910803
1010	1020100	1030301000	31.7804972	10.0332228	.0009900990
1011	1022121	1033364331	31.7962262	10.0365330	.0009891197
1012	1024144	1036433728	31.8119474	10.0398410	.0009881423
1013	1026169	1039509197	31.8276609	10.0431469	.0009871668
1014	1028196	1042590744	31.8433666	10.0464506	.0009861933
1015	1030225	1045678375	31.8590646	10.0497521	.0009852217
1016	1032256	1048772096	31.8747549	10.0530514	.0009842520
1017	1034289	1051871913	31.8904374	10.0563485	.0009832842
1018	1036324	1054977832	31.9061123	10.0596435	.0009823183
1019	1038361	1058089859	31.9217794	10.0629364	.0009813543
1020	1040400	1061208000	31.9374388	10.0662271	.0009803922
1021	1042441	1064332261	31.9530906	10.0695156	.0009794319
1022	1044484	1067462648	31.9687347	10.0728020	.0009784736
1023	1046529	1070599167	31.9843712	10.0760863	.0009775171
1024	1048576	1073741824	32.0000000	10.0793684	.0009765625
1025	1050625	1076890625	32.0156212	10.0826484	.0009756098
1026	1052676	1080045576	32.0312348	10.0859262	.0009746589
1027	1054729	1083206683	32.0468407	10 0892019	.0009737098
1028	1056784	1086373952	32.0624391	10.0924755	.0009727626
1029	1058841	1089547389	32.0780298	10.0957469	.0009718173
1030	1060900	1092727000	32.0936131	10.0990163	.0009708738
1031	1062961	1095912791	32.1091887	10.1022835	.0009699321
1032	1065024	1099104768	32.1247568	10.1055487	.0009689922
1033	1067089	1102302937	32.1403173	10.1088117	.0009680542
1034	1069156	1105507304	32.1558704	10.1120726	.0009671180
1035	1071225	1108717875	32.1714159	10.1153314	.0009661836
1036	1073296	1111934656	32.1869539	10.1185882	.0009652510
1037	1075369	1115157653	32.2024844	10.1218428	.0009643202
1038	1077444	1118386872	32.2180074	10.1250953	.0009633911
1039	1079521	1121622319	32.2335229	10.1283457	.0009624639
1040	1081600	1124864000	32.2490310	10.1315941	.0009615385
1041	1083681	1128111921	32.2645316	10.1348403	.0009606148
1042	1085764	1131366088	32.2800248	10.1380845	.0009596929
1043	1087849	1134626507	32.2955105	10.1413266	.0009587738
1044	1089936	1137893184	32.3109888	10.1445667	.0009578544
1045	1092025	1141166125	32.3264598	10.1478047	.0009569378
1046	1094116	1144445336	32.3419233	10 1510406	.0009560229
1047	1096209	1147730823	32.3573794	10 1542744	.0009551098
1048	1098304	1151022592	32.3728281	10.1575062	.0009541985
1049	1100401	1154320649	32.3882695	10.1607359	.0009532888
1050	1102500	1157625000	32.4037035	10.1639636	.0009523810
1051	1104601	1160935651	32.4191301	10.1671893	.0009514748
1052	1106704	1164252608	32.4345495	10.1704129	.0009505703
1053	1108809	1167575877	32.4499615	10.1736344	.0009496676
	1110916	1170905464	32.4653662	10.1768539	.0009487666

TABLE 83.

LOGARITHMS OF NUMBERS

FROM

1 to 10,000

TO SIX DECIMAL PLACES.

N.	Log.	N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0.000000	21	1.322219	41	1.612784	61	1.785330	81	1.908485
2	0.301030	22	1.342423	42	1.623249	62	1.792392	82	1.913814
3	0.477121	23	1.361728	43	1.633468	63	1.799341	83	1.919078
4	0.602060	24	1.380211	44	1.643453	64	1.806180	84	1.924279
5	0.698970	25	1.397940	45	1.653213	65	1.812913	85	1.929419
6	0.778151	26	1.414973	46	1.662758	66	1.819544	86	1.934498
7	0.845098	27	1.431364	47	1.672098	67	1.826075	87	1.939519
8	0.903090	28	1.447158	48	1.681241	68	1.832509	88	1.944483
9	0.954243	29	1.462398	49	1.690196	69	1.838849	89	1.949390
10	1.000000	30	1.477121	50	1.698970	70	1.845098	90	1.954243
11	1.041393	31	1.491362	51	1.707570	71	1.851258	91	1.959041
12	1.079181	32	1.505150	52	1.716003	72	1.857332	92	1.963788
13	1.113943	33	1.518514	53	1.724276	73	1.863323	93	1.968483
14	1.146128	34	1.531479	54	1.732394	74	1.869232	94	1.973128
15	1.176091	35	1.544068	55	1.740363	75	1.875061	95	1.977724
16	1.204120	36	1.556303	56	1.748188	76	1.880814	96	1.982271
17	1.230449	37	1.568202	57	1.755875	77	1.886491	97	1.986772
18	1.255273	38	1.579784	58	1.763428	78	1.892095	98	1.991226
19	1.278754	39	1.591065	59	1.770852	79	1.897627	99	1.995635
20	1.301030	40	1.602060	60	1.778151	80	1.903090	100	2.000000

No. 100 L. 000.] [No. 109 L. 040.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
100	000000	0434	0868	1301	1734	2166	2598	3029	3461	3891	432
1	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
2	8600	9026	9451	9876	0300	0724	1147	1570	1993	2415	424
3	012837	3259	3680	4100	4521	4940	5360	5779	6197	6616	420
4	7033	7451	7868	8284	8700	9116	9532	9947	0361	0775	416
5	021189	1603	2016	2428	2841	3252	3664	4075	4486	4896	412
6	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
7	9384	9789	0195	0600	1004	1408	1812	2216	2619	3021	404
8	033424	3826	4227	4628	5029	5430	5830	6230	6629	7028	400
9	7426	7825	8223	8620	9017	9414	9811				
	04							0207	0602	0998	397

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
434	43.4	86.8	130.2	173.6	217.0	260.4	303.8	347.2	390.6
433	43.3	86.6	129.9	173.2	216.5	259.8	303.1	346.4	389.7
432	43.2	86.4	129.6	172.8	216.0	259.2	302.4	345.6	388.8
431	43.1	86.2	129.3	172.4	215.5	258.6	301.7	344.8	387.9
430	43.0	86.0	129.0	172.0	215.0	258.0	301.0	344.0	387.0
429	42.9	85.8	128.7	171.6	214.5	257.4	300.3	343.2	386.1
428	42.8	85.6	128.4	171.2	214.0	256.8	299.6	342.4	385.2
427	42.7	85.4	128.1	170.8	213.5	256.2	298.9	341.6	384.3
426	42.6	85.2	127.8	170.4	213.0	255.6	298.2	340.8	383.4
425	42.5	85.0	127.5	170.0	212.5	255.0	297.5	340.0	382.5
424	42.4	84.8	127.2	169.6	212.0	254.4	296.8	339.2	381.6
423	42.3	84.6	126.9	169.2	211.5	253.8	296.1	338.4	380.7
422	42.2	84.4	126.6	168.8	211.0	253.2	295.4	337.6	379.8
421	42.1	84.2	126.3	168.4	210.5	252.6	294.7	336.8	378.9
420	42.0	84.0	126.0	168.0	210.0	252.0	294.0	336.0	378.0
419	41.9	83.8	125.7	167.6	209.5	251.4	293.3	335.2	377.1
418	41.8	83.6	125.4	167.2	209.0	250.8	292.6	334.4	376.2
417	41.7	83.4	125.1	166.8	208.5	250.2	291.9	333.6	375.3
416	41.6	83.2	124.8	166.4	208.0	249.6	291.2	332.8	374.4
415	41.5	83.0	124.5	166.0	207.5	249.0	290.5	332.0	373.5
414	41.4	82.8	124.2	165.6	207.0	248.4	289.8	331.2	372.6
413	41.3	82.6	123.9	165.2	206.5	247.8	289.1	330.4	371.7
412	41.2	82.4	123.6	164.8	206.0	247.2	288.4	329.6	370.8
411	41.1	82.2	123.3	164.4	205.5	246.6	287.7	328.8	369.9
410	41.0	82.0	123.0	164.0	205.0	246.0	287.0	328.0	369.0
409	40.9	81.8	122.7	163.6	204.5	245.4	286.3	327.2	368.1
408	40.8	81.6	122.4	163.2	204.0	244.8	285.6	326.4	367.2
407	40.7	81.4	122.1	162.8	203.5	244.2	284.9	325.6	366.3
406	40.6	81.2	121.8	162.4	203.0	243.6	284.2	324.8	365.4
405	40.5	81.0	121.5	162.0	202.5	243.0	283.5	324.0	364.5
404	40.4	80.8	121.2	161.6	202.0	242.4	282.8	323.2	363.6
403	40.3	80.6	120.9	161.2	201.5	241.8	282.1	322.4	362.7
402	40.2	80.4	120.6	160.8	201.0	241.2	281.4	321.6	361.8
401	40.1	80.2	120.3	160.4	200.5	240.6	280.7	320.8	360.9
400	40.0	80.0	120.0	160.0	200.0	240.0	280.0	320.0	360.0
399	39.9	79.8	119.7	159.6	199.5	239.4	279.3	319.2	359.1
398	39.8	79.6	119.4	159.2	199.0	238.8	278.6	318.4	358.2
397	39.7	79.4	119.1	158.8	198.5	238.2	277.9	317.6	357.3
396	39.6	79.2	118.8	158.4	198.0	237.6	277.2	316.8	356.4
395	39.5	79.0	118.5	158.0	197.5	237.0	276.5	316.0	355.5

No. 110 L. 041.] [No. 119 L. 078.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
110	041393	1787	2182	2576	2969	3362	3755	4148	4540	4932	393
1	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
2	9218	9606	9993	0380	0766	1153	1538	1924	2309	2694	386
3	053078	3463	3846	4230	4613	4996	5378	5760	6142	6524	383
4	6905	7286	7666	8046	8426	8805	9185	9563	9942	0320	379
5	060698	1075	1452	1829	2206	2582	2958	3333	3709	4083	376
6	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
7	8186	8557	8928	9298	9668	0038	0407	0776	1145	1514	370
8	071882	2250	2617	2985	3352	3718	4085	4451	4816	5182	366
9	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363

PROPORTIONAL PARTS.

Diff									
395	39.5	79.0	118.5	158.0	197.5	237.0	276.5	316.0	355.5
394	39.4	78.8	118.2	157.6	197.0	236.4	275.8	315.2	354.6
393	39.3	78.6	117.9	157.2	196.5	235.8	275.1	314.4	353.7
392	39.2	78.4	117.6	156.8	196.0	235.2	274.4	313.6	352.8
391	39.1	78.2	117.3	156.4	195.5	234.6	273.7	312.8	351.9
390	39.0	78.0	117.0	156.0	195.0	234.0	273.0	312.0	351.0
389	38.9	77.8	116.7	155.6	194.5	233.4	272.3	311.2	350.1
388	38.8	77.6	116.4	155.2	194.0	232.8	271.6	310.4	349.2
387	38.7	77.4	116.1	154.8	193.5	232.2	270.9	309.6	348.3
386	38.6	77.2	115.8	154.4	193.0	231.6	270.2	308.8	347.4
385	38.5	77.0	115.5	154.0	192.5	231.0	269.5	308.0	346.5
384	38.4	76.8	115.2	153.6	192.0	230.4	268.8	307.2	345.6
383	38.3	76.6	114.9	153.2	191.5	229.8	268.1	306.4	344.7
382	38.2	76.4	114.6	152.8	191.0	229.2	267.4	305.6	343.8
381	38.1	76.2	114.3	152.4	190.5	228.6	266.7	304.8	342.9
380	38.0	76.0	114.0	152.0	190.0	228.0	266.0	304.0	342.0
379	37.9	75.8	113.7	151.6	189.5	227.4	265.3	303.2	341.1
378	37.8	75.6	113.4	151.2	189.0	226.8	264.6	302.4	340.2
377	37.7	75.4	113.1	150.8	188.5	226.2	263.9	301.6	339.3
376	37.6	75.2	112.8	150.4	188.0	225.6	263.2	300.8	338.4
375	37.5	75.0	112.5	150.0	187.5	225.0	262.5	300.0	337.5
374	37.4	74.8	112.2	149.6	187.0	224.4	261.8	299.2	336.6
373	37.3	74.6	111.9	149.2	186.5	223.8	261.1	298.4	335.7
372	37.2	74.4	111.6	148.8	186.0	223.2	260.4	297.6	334.8
371	37.1	74.2	111.3	148.4	185.5	222.6	259.7	296.8	333.9
370	37.0	74.0	111.0	148.0	185.0	222.0	259.0	296.0	333.0
369	36.9	73.8	110.7	147.6	184.5	221.4	258.3	295.2	332.1
368	36.8	73.6	110.4	147.2	184.0	220.8	257.6	294.4	331.2
367	36.7	73.4	110.1	146.8	183.5	220.2	256.9	293.6	330.3
366	36.6	73.2	109.8	146.4	183.0	219.6	256.2	292.8	329.4
365	36.5	73.0	109.5	146.0	182.5	219.0	255.7	292.0	328.5
364	36.4	72.8	109.2	145.6	182.0	218.4	254.8	291.2	327.6
363	36.3	72.6	108.9	145.2	181.5	217.8	254.1	290.4	326.7
362	36.2	72.4	108.6	144.8	181.0	217.2	253.4	289.6	325.8
361	36.1	72.2	108.3	144.4	180.5	216.6	252.7	288.8	324.9
360	36.0	72.0	108.0	144.0	180.0	216.0	252.0	288.0	324.0
359	35.9	71.8	107.7	143.6	179.5	215.4	251.3	287.2	323.1
358	35.8	71.6	107.4	143.2	179.0	214.8	250.6	286.4	322.2
357	35.7	71.4	107.1	142.8	178.5	214.2	249.9	285.6	321.3
356	35.6	71.2	106.8	142.4	178.0	213.6	249.2	284.8	320.4

N.	0	1	2	3	4	5	6	7	8	9	Diff.
120	079181	9543	9904	0266	0626	0987	1347	1707	2067	2426	360
1	082785	3144	3503	3861	4219	4576	4934	5291	5647	6004	357
2	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
3	9905	0258	0611	0963	1315	1667	2018	2370	2721	3071	352
4	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
5	6910	7257	7604	7951	8298	8644	8990	9335	9681	0026	346
6	100371	0715	1059	1403	1747	2091	2434	2777	3119	3462	343
7	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
8	7210	7549	7888	8227	8565	8903	9241	9579	9916	0253	338
9	110590	0926	1263	1599	1934	2270	2605	2940	3275	3609	335
130	3943	4277	4611	4944	5278	5611	5943	6276	6608	6940	333
1	7271	7603	7934	8265	8595	8926	9256	9586	9915	0245	330
2	120574	0903	1231	1560	1888	2216	2544	2871	3198	3525	328
3	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
4	7105 13	7429	7753	8076	8399	8722	9045	9368	9690	0012	323

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
355	35.5	71.0	106.5	142.0	177.5	213.0	248.5	284.0	319.5
354	35.4	70.8	106.2	141.6	177.0	212.4	247.8	283.2	318.6
353	35.3	70.6	105.9	141.2	176.5	211.8	247.1	282.4	317.7
352	35.2	70.4	105.6	140.8	176.0	211.2	246.4	281.6	316.8
351	35.1	70.2	105.3	140.4	175.5	210.6	245.7	280.8	315.9
350	35.0	70.0	105.0	140.0	175.0	210.0	245.0	280.0	315.0
349	34.9	69.8	104.7	139.6	174.5	209.4	244.3	279.2	314.1
348	34.8	69.6	104.4	139.2	174.0	208.8	243.6	278.4	313.2
347	34.7	69.4	104.1	138.8	173.5	208.2	242.9	277.6	312.3
346	34.6	69.2	103.8	138.4	173.0	207.6	242.2	276.8	311.4
345	34.5	69.0	103.5	138.0	172.5	207.0	241.5	276.0	310.5
344	34.4	68.8	103.2	137.6	172.0	206.4	240.8	275.2	309.6
343	34.3	68.6	102.9	137.2	171.5	205.8	240.1	274.4	308.7
342	34.2	68.4	102.6	136.8	171.0	205.2	239.4	273.6	307.8
341	34.1	68.2	102.3	136.4	170.5	204.6	238.7	272.8	306.9
340	34.0	68.0	102.0	136.0	170.0	204.0	238.0	272.0	306.0
339	33.9	67.8	101.7	135.6	169.5	203.4	237.3	271.2	305.1
338	33.8	67.6	101.4	135.2	169.0	202.8	236.6	270.4	304.2
337	33.7	67.4	101.1	134.8	168.5	202.2	235.9	269.6	303.3
336	33.6	67.2	100.8	134.4	168.0	201.6	235.2	268.8	302.4
335	33.5	67.0	100.5	134.0	167.5	201.0	234.5	268.0	301.5
334	33.4	66.8	100.2	133.6	167.0	200.4	233.8	267.2	300.6
333	33.3	66.6	99.9	133.2	166.5	199.8	233.1	266.4	299.7
332	33.2	66.4	99.6	132.8	166.0	199.2	232.4	265.6	298.8
331	33.1	66.2	99.3	132.4	165.5	198.6	231.7	264.8	297.9
330	33.0	66.0	99.0	132.0	165.0	198.0	231.0	264.0	297.0
329	32.9	65.8	98.7	131.6	164.5	197.4	230.3	263.2	296.1
328	32.8	65.6	98.4	131.2	164.0	196.8	229.6	262.4	295.2
327	32.7	65.4	98.1	130.8	163.5	196.2	228.9	261.6	294.3
326	32.6	65.2	97.8	130.4	163.0	195.6	228.2	260.8	293.4
325	32.5	65.0	97.5	130.0	162.5	195.0	227.5	260.0	292.5
324	32.4	64.8	97.2	129.6	162.0	194.4	226.8	259.2	291.6
323	32.3	64.6	96.9	129.2	161.5	193.8	226.1	258.4	290.7
322	32.2	64.4	96.6	128.8	161.0	193.2	225.4	257.6	289.8

No. 135 L. 130.]										[No. 149 L. 175.
N.	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Diff.**
135	130334	0655	0977	1298	1619	1939	2260	2580	2900	3219	321
6	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
7	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
8	9879	0194	0508	0822	1136	1450	1763	2076	2389	2702	314
9	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	6128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
1	9219	9527	9835	0142	0449	0756	1063	1370	1676	1982	307
2	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	305
3	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
4	8362	8664	8965	9266	9567	9868	0168	0469	0769	1068	301
5	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	299
6	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
7	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
8	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	293
9	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
321	32.1	64.2	96.3	128.4	160.5	192.6	224.7	256.8	288.9
320	32.0	64.0	96.0	128.0	160.0	192.0	224.0	256.0	288.0
319	31.9	63.8	95.7	127.6	159.5	191.4	223.3	255.2	287.1
318	31.8	63.6	95.4	127.2	159.0	190.8	222.6	254.4	286.2
317	31.7	63.4	95.1	126.8	158.5	190.2	221.9	253.6	285.3
316	31.6	63.2	94.8	126.4	158.0	189.6	221.2	252.8	284.4
315	31.5	63.0	94.5	126.0	157.5	189.0	220.5	252.0	283.5
314	31.4	62.8	94.2	125.6	157.0	188.4	219.8	251.2	282.6
313	31.3	62.6	93.9	125.2	156.5	187.8	219.1	250.4	281.7
312	31.2	62.4	93.6	124.8	156.0	187.2	218.4	249.6	280.8
311	31.1	62.2	93.3	124.4	155.5	186.6	217.7	248.8	279.9
310	31.0	62.0	93.0	124.0	155.0	186.0	217.0	248.0	279.0
309	30.9	61.8	92.7	123.6	154.5	185.4	216.3	247.2	278.1
308	30.8	61.6	92.4	123.2	154.0	184.8	215.6	246.4	277.2
307	30.7	61.4	92.1	122.8	153.5	184.2	214.9	245.6	276.3
306	30.6	61.2	91.8	122.4	153.0	183.6	214.2	244.8	275.4
305	30.5	61.0	91.5	122.0	152.5	183.0	213.5	244.0	274.5
304	30.4	60.8	91.2	121.6	152.0	182.4	212.8	243.2	273.6
303	30.3	60.6	90.9	121.2	151.5	181.8	212.1	242.4	272.7
302	30.2	60.4	90.6	120.8	151.0	181.2	211.4	241.6	271.8
301	30.1	60.2	90.3	120.4	150.5	180.6	210.7	240.8	270.9
300	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0
299	29.9	59.8	89.7	119.6	149.5	179.4	209.3	239.2	269.1
298	29.8	59.6	89.4	119.2	149.0	178.8	208.6	238.4	268.2
297	29.7	59.4	89.1	118.8	148.5	178.2	207.9	237.6	267.3
296	29.6	59.2	88.8	118.4	148.0	177.6	207.2	236.8	266.4
295	29.5	59.0	88.5	118.0	147.5	177.0	206.5	236.0	265.5
294	29.4	58.8	88.2	117.6	147.0	176.4	205.8	235.2	264.6
293	29.3	58.6	87.9	117.2	146.5	175.8	205.1	234.4	263.7
292	29.2	58.4	87.6	116.8	146.0	175.2	204.4	233.6	262.8
291	29.1	58.2	87.3	116.4	145.5	174.6	203.7	232.8	261.9
290	29.0	58.0	87.0	116.0	145.0	174.0	203.0	232.0	261.0
289	28.9	57.8	86.7	115.6	144.5	173.4	202.3	231.2	260.1
288	28.8	57.6	86.4	115.2	144.0	172.8	201.6	230.4	259.2
287	28.7	57.4	86.1	114.8	143.5	172.2	200.9	229.6	258.3
286	28.6	57.2	85.8	114.4	143.0	171.6	200.2	228.8	257.4

No. 150 L. 176.] [No. 169 L. 230.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
150	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
1	8977	9264	9552	9839	0126	0413	0699	0986	1272	1558	287
2	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
3	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
4	7521	7803	8084	8366	8647	8928	9209	9490	9771	0051	281
5	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
6	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
7	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
8	8657	8932	9206	9481	9755	0029	0303	0577	0850	1124	274
9	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272
160	4120	4391	4663	4934	5204	5475	5746	6016	6286	6556	271
1	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
2	9515	9783	0051	0319	0586	0853	1121	1388	1654	1921	267
3	212188	2454	2720	2986	3252	3518	3783	4049	4314	4579	266
4	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
5	7484	7747	8010	8273	8536	8798	9060	9323	9585	9846	262
6	220108	0370	0631	0892	1153	1414	1675	1936	2196	2456	261
7	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
8	5309	5568	5826	6084	6342	6600	6858	7115	7372	7630	258
9	7887	8144	8400	8657	8913	9170	9426	9682	9938	0193	256
	23										

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
285	28.5	57.0	85.5	114.0	142.5	171.0	199.5	228.0	256.5
284	28.4	56.8	85.2	113.6	142.0	170.4	198.8	227.2	255.6
283	28.3	56.6	84.9	113.2	141.5	169.8	198.1	226.4	254.7
282	28.2	56.4	84.6	112.8	141.0	169.2	197.4	225.6	253.8
281	28.1	56.2	84.3	112 4	140.5	168.6	196.7	224.8	252.9
280	28.0	56.0	84.0	112.0	140.0	168.0	196.0	224.0	252.0
279	27.9	55.8	83.7	111.6	139.5	167.4	195.3	223.2	251.1
278	27.8	55.6	83.4	111.2	139.0	166.8	194.6	222.4	250.2
277	27.7	55.4	83.1	110.8	138.5	166.2	193.9	221.6	249.3
276	27.6	55.2	82.8	110.4	138.0	165.6	193.2	220.8	248.4
275	27.5	55.0	82.5	110.0	137.5	165.0	192.5	220.0	247.5
274	27.4	54.8	82.2	109.6	137.0	164.4	191.8	219.2	246.6
273	27.3	54.6	81.9	109.2	136.5	163.8	191.1	218.4	245.7
272	27.2	54.4	81.6	108.8	136.0	163.2	190.4	217.6	244.8
271	27.1	54.2	81.3	108.4	135.5	162.6	189.7	216.8	243.9
270	27.0	54.0	81.0	108.0	135.0	162.0	189.0	216.0	243.0
269	26.9	53.8	80.7	107.6	134.5	161.4	188.3	215.2	242.1
268	26.8	53.6	80.4	107.2	134.0	160.8	187.6	214.4	241.2
267	26.7	53.4	80.1	106.8	133.5	160.2	186.9	213.6	240.3
266	26.6	53.2	79.8	106.4	133.0	159.6	186.2	212.8	239.4
265	26.5	53.0	79.5	106.0	132.5	159.0	185.5	212.0	238.5
264	26.4	52.8	79.2	105.6	132.0	158.4	184.8	211.2	237.6
263	26.3	52.6	78.9	105.2	131.5	157.8	184.1	210.4	236.7
262	26.2	52.4	78.6	104.8	131.0	157.2	183.4	209.6	235.8
261	26.1	52.2	78.3	104.4	130.5	156.6	182.7	208.8	234.9
260	26.0	52.0	78.0	104.0	130.0	156.0	182.0	208.0	234.0
259	25.9	51.8	77.7	103.6	129.5	155.4	181.3	207.2	233.1
258	25.8	51.6	77.4	103.2	129.0	154.8	180.6	206.4	232.2
257	25.7	51.4	77.1	102.8	128.5	154.2	179.9	205.6	231.3
256	25.6	51.2	76.8	102.4	128.0	153.6	179.2	204.8	230.4
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5

No. 170 L. 230.] [No. 189 L. 278.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
170	230449	0704	0960	1215	1470	1724	1979	2234	2488	2742	255
1	2996	3250	3504	3757	4011	4264	4517	4770	5023	5276	253
2	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
3	8046	8297	8548	8799	9049	9299	9550	9800	0050	0300	250
4	240549	0799	1048	1297	1546	1795	2044	2293	2541	2790	249
5	3038	3286	3534	3782	4030	4277	4525	4772	5019	5266	248
6	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
7	7973	8219	8464	8709	8954	9198	9443	9687	9932	0176	245
8	250420	0664	0908	1151	1395	1638	1881	2125	2368	2610	243
9	2853	3096	3338	3580	3822	4064	4306	4548	4790	5031	242
180	5273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
1	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
2	260071	0310	0548	0787	1025	1263	1501	1739	1976	2214	238
3	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
4	4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
5	7172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
6	9513	9746	9980	0213	0446	0679	0912	1144	1377	1609	233
7	271842	2074	2306	2538	2770	3001	3233	3464	3696	3927	232
8	4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
9	6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229

PROPORTIONAL PARTS.

Diff.									
255	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5
254	25.4	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6
253	25.3	50.6	75.9	101.2	126.5	151.8	177.1	202.4	227.7
252	25.2	50.4	75.6	100.8	126.0	151.2	176.4	201.6	226.8
251	25.1	50.2	75.3	100.4	125.5	150.6	175.7	200.8	225.9
250	25.0	50.0	75.0	100.0	125.0	150.0	175.0	200.0	225.0
249	24.9	49.8	74.7	99.6	124.5	149.4	174.3	199.2	224.1
248	24.8	49.6	74.4	99.2	124.0	148.8	173.6	198.4	223.2
247	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.6	222.3
246	24.6	49.2	73.8	98.4	123.0	147.6	172.2	196.8	221.4
245	24.5	49.0	73.5	98.0	122.5	147.0	171.5	196.0	220.5
244	24.4	48.8	73.2	97.6	122.0	146.4	170.8	195.2	219.6
243	24.3	48.6	72.9	97.2	121.5	145.8	170.1	194.4	218.7
242	24.2	48.4	72.6	96.8	121.0	145.2	169.4	193.6	217.8
241	24.1	48.2	72.3	96.4	120.5	144.6	168.7	192.8	216.9
240	24.0	48.0	72.0	96.0	120.0	144.0	168.0	192.0	216.0
239	23.9	47.8	71.7	95.6	119.5	143.4	167.3	191.2	215.1
238	23.8	47.6	71.4	95.2	119.0	142.8	166.6	190.4	214.2
237	23.7	47.4	71.1	94.8	118.5	142.2	165.9	189.6	213.3
236	23.6	47.2	70.8	94.4	118.0	141.6	165.2	188.8	212.4
235	23.5	47.0	70.5	94.0	117.5	141.0	164.5	188.0	211.5
234	23.4	46.8	70.2	93.6	117.0	140.4	163.8	187.2	210.6
233	23.3	46.6	69.9	93.2	116.5	139.8	163.1	186.4	209.7
232	23.2	46.4	69.6	92.8	116.0	139.2	162.4	185.6	208.8
231	23.1	46.2	69.3	92.4	115.5	138.6	161.7	184.8	207.9
230	23.0	46.0	69.0	92.0	115.0	138.0	161.0	184.0	207.0
229	22.9	45.8	68.7	91.6	114.5	137.4	160.3	183.2	206.1
228	22.8	45.6	68.4	91.2	114.0	136.8	159.6	182.4	205.2
227	22.7	45.4	68.1	90.8	113.5	136.2	158.9	181.6	204.3
226	22.6	45.2	67.8	90.4	113.0	135.6	158.2	180.8	203.4

No. 190 L. 278.] [No. 214 L. 332.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
190	278754	8982	9211	9439	9667	9895	0123	0351	0578	0806	228
1	281033	1261	1488	1715	1942	2169	2396	2622	2849	3075	227
2	3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
3	5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
4	7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
5	290035	0257	0480	0702	0925	1147	1369	1591	1813	2034	222
6	2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
7	4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
8	6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
9	8853	9071	9289	9507	9725	9943	0161	0378	0595	0813	218
200	301030	1247	1464	1681	1898	2114	2331	2547	2764	2980	217
1	3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
2	5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
3	7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
4	9630	9843	0056	0268	0481	0693	0906	1118	1330	1542	212
5	311754	1966	2177	2389	2600	2812	3023	3234	3445	3656	211
6	3867	4078	4289	4499	4710	4920	5130	5340	5551	5760	210
7	5970	6180	6390	6599	6809	7018	7227	7436	7646	7854	209
8	8063	8272	8481	8689	8898	9106	9314	9522	9730	9938	208
9	320146	0354	0562	0769	0977	1184	1391	1598	1805	2012	207
210	2219	2426	2633	2839	3046	3252	3458	3665	3871	4077	206
1	4282	4488	4694	4899	5105	5310	5516	5721	5926	6131	205
2	6336	6541	6745	6950	7155	7359	7563	7767	7972	8176	204
3	8380	8583	8787	8991	9194	9398	9601	9805	0008	0211	203
4	330414	0617	0819	1022	1225	1427	1630	1832	2034	2236	202

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
225	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5
224	22.4	44.8	67.2	89.6	112.0	134.4	156.8	179.2	201.6
223	22.3	44.6	66.9	89.2	111.5	133.8	156.1	178.4	200.7
222	22.2	44.4	66.6	88.8	111.0	133.2	155.4	177.6	199.8
221	22.1	44.2	66.3	88.4	110.5	132.6	154.7	176.8	198.9
220	22.0	44.0	66.0	88.0	110.0	132.0	154.0	176.0	198.0
219	21.9	43.8	65.7	87.6	109.5	131.4	153.3	175.2	197.1
218	21.8	43.6	65.4	87.2	109.0	130.8	152.6	174.4	196.2
217	21.7	43.4	65.1	86.8	108.5	130.2	151.9	173.6	195.3
216	21.6	43.2	64.8	86.4	108.0	129.6	151.2	172.8	194.4
215	21.5	43.0	64.5	86.0	107.5	129.0	150.5	172.0	193.5
214	21.4	42.8	64.2	85.6	107.0	128.4	149.8	171.2	192.6
213	21.3	42.6	63.9	85.2	106.5	127.8	149.1	170.4	191.7
212	21.2	42.4	63.6	84.8	106.0	127.2	148.4	169.6	190.8
211	21.1	42.2	63.3	84.4	105.5	126.6	147.7	168.8	189.9
210	21.0	42.0	63.0	84.0	105.0	126.0	147.0	168.0	189.0
209	20.9	41.8	62.7	83.6	104.5	125.4	146.3	167.2	188.1
208	20.8	41.6	62.4	83.2	104.0	124.8	145.6	166.4	187.2
207	20.7	41.4	62.1	82.8	103.5	124.2	144.9	165.6	186.3
206	20.6	41.2	61.8	82.4	103.0	123.6	144.2	164.8	185.4
205	20.5	41.0	61.5	82.0	102.5	123.0	143.5	164.0	184.5
204	20.4	40.8	61.2	81.6	102.0	122.4	142.8	163.2	183.6
203	20.3	40.6	60.9	81.2	101.5	121.8	142.1	162.4	182.7
202	20.2	40.4	60.6	80.8	101.0	121.2	141.4	161.6	181.8

No. 215 L. 332.] [No. 239 L. 380.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
215	332438	2640	2842	3044	3246	3447	3649	3850	4051	4253	202
6	4454	4655	4856	5057	5257	5458	5658	5859	6059	6260	201
7	6460	6660	6860	7060	7260	7459	7659	7858	8058	8257	200
8	8456	8656	8855	9054	9253	9451	9650	9849	0047	0246	199
9	340444	0642	0841	1039	1237	1435	1632	1830	2028	2225	198
220	2423	2620	2817	3014	3212	3409	3606	3802	3999	4196	197
1	4392	4589	4785	4981	5178	5374	5570	5766	5962	6157	196
2	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
3	8305	8500	8694	8889	9083	9278	9472	9666	9860	0054	194
4	350248	0442	0636	0829	1023	1216	1410	1603	1796	1989	193
5	2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
6	4108	4301	4493	4685	4876	5068	5260	5452	5643	5834	192
7	6026	6217	6408	6599	6790	6981	7172	7363	7554	7744	191
8	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
9	9835	0025	0215	0404	0593	0783	0972	1161	1350	1539	189
230	361728	1917	2105	2294	2482	2671	2859	3048	3236	3424	188
1	3612	3800	3988	4176	4363	4551	4739	4926	5113	5301	188
2	5488	5675	5862	6049	6236	6423	6610	6796	6983	7169	187
3	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
4	9216	9401	9587	9772	9958	0143	0328	0513	0698	0883	185
5	371068	1253	1437	1622	1806	1991	2175	2360	2544	2728	184
6	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
7	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
8	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
9	8398	8580	8761	8943	9124	9306	9487	9668	9849	0030	181
	38										

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
202	20.2	40.4	60.6	80.8	101.0	121.2	141.4	161.6	181.8
201	20.1	40.2	60.3	80.4	100.5	120.6	140.7	160.8	180.9
200	20.0	40.0	60.0	80.0	100.0	120.0	140.0	160.0	180.0
199	19.9	39.8	59.7	79.6	99.5	119.4	139.3	159.2	179.1
198	19.8	39.6	59.4	79.2	99.0	118.8	138.6	158.4	178.2
197	19.7	39.4	59.1	78.8	98.5	118.2	137.9	157.6	177.3
196	19.6	39.2	58.8	78.4	98.0	117.6	137.2	156.8	176.4
195	19.5	39.0	58.5	78.0	97 5	117.0	136.5	156.0	175.5
194	19.4	38.8	58.2	77.6	97.0	116.4	135.8	155.2	174.6
193	19.3	38.6	57.9	77.2	96.5	115.8	135.1	154.4	173.7
192	19.2	38.4	57.6	76.8	96.0	115.2	134.4	153.6	172.8
191	19.1	38.2	57.3	76.4	95.5	114.6	133.7	152.8	171.9
190	19.0	38.0	57.0	76.0	95.0	114.0	133.0	152.0	171.0
189	18.9	37.8	56.7	75.6	94.5	113.4	132.3	151.2	170.1
188	18.8	37.6	56.4	75.2	94.0	112.8	131.6	150.4	169.2
187	18.7	37 4	56.1	74.8	93.5	112.2	130.9	149.6	168.3
186	18.6	37.2	55.8	74.4	93.0	111.6	130.2	148.8	167.4
185	18.5	37.0	55.5	74.0	92.5	111.0	129.5	148.0	166.5
184	18.4	36.8	55.2	73.6	92.0	110.4	128.8	147.2	165.6
183	18.3	36.6	54.9	73.2	91.5	109.8	128.1	146.4	164.7
182	18.2	36.4	54.6	72.8	91.0	109.2	127.4	145.6	163.8
181	18.1	36.2	54.3	72.4	90.5	108.6	126.7	144.8	162.9
180	18.0	36.0	54.0	72.0	90.0	108.0	126.0	144.0	162.0
179	17.9	35.8	53.7	71.6	89.5	107.4	125.3	143.2	161.1

No. 240 L. 380.]											[No. 269 L. 431.
N.	0	1	2	3	4	5	6	7	8	9	Diff.
240	380211	0392	0573	0754	0934	1115	1296	1476	1656	1837	181
1	2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
2	3815	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
3	5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
4	7390	7568	7746	7924	8101	8279	8456	8634	8811	8989	178
5	9166	9343	9520	9698	9875	0051	0228	0405	0582	0759	177
6	390935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
7	2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
8	4452	4627	4802	4977	5152	5326	5501	5676	5850	6025	175
9	6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
250	7940	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
1	9674	9847	0020	0192	0365	0538	0711	0883	1056	1228	173
2	401401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
3	3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
4	4834	5005	5176	5346	5517	5688	5858	6029	6199	6370	171
5	6540	6710	6881	7051	7221	7391	7561	7731	7901	8070	170
6	8240	8410	8579	8749	8918	9087	9257	9426	9595	9764	169
7	9933	0102	0271	0440	0609	0777	0946	1114	1283	1451	169
8	411620	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
9	3300	3467	3635	3803	3970	4137	4305	4472	4639	4806	167
260	4973	5140	5307	5474	5641	5808	5974	6141	6308	6474	167
1	6641	6807	6973	7139	7306	7472	7638	7804	7970	8135	166
2	8301	8467	8633	8798	8964	9129	9295	9460	9625	9791	165
3	9956	0121	0286	0451	0616	0781	0945	1110	1275	1439	165
4	421604	1768	1933	2097	2261	2426	2590	2754	2918	3082	164
5	3246	3410	3574	3737	3901	4065	4228	4392	4555	4718	164
6	4882	5045	5208	5371	5534	5697	5860	6023	6186	6349	163
7	6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
8	8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
9	9752 43	9914	0075	0236	0398	0559	0720	0881	1042	1203	161

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
178	17.8	35.6	53.4	71.2	89.0	106.8	124.6	142.4	160.2
177	17.7	35.4	53.1	70.8	88.5	106.2	123.9	141.6	159.3
176	17.6	35.2	52.8	70.4	88.0	105.6	123.2	140.8	158.4
175	17.5	35.0	52.5	70.0	87.5	105.0	122.5	140.0	157.5
174	17.4	34.8	52.2	69.6	87.0	104.4	121.8	139.2	156.6
173	17.3	34.6	51.9	69.2	86.5	103.8	121.1	138.4	155.7
172	17.2	34.4	51.6	68.8	86.0	103.2	120.4	137.6	154.8
171	17.1	34.2	51.3	68.4	85.5	102.6	119.7	136.8	153.9
170	17.0	34.0	51.0	68.0	85.0	102.0	119.0	136.0	153.0
169	16.9	33.8	50.7	67.6	84.5	101.4	118.3	135.2	152.1
168	16.8	33.6	50.4	67.2	84.0	100.8	117.6	134.4	151.2
167	16.7	33.4	50.1	66.8	83.5	100.2	116.9	133.6	150.3
166	16.6	33.2	49.8	66.4	83.0	99.6	116.2	132.8	149.4
165	16.5	33.0	49.5	66.0	82.5	99.0	115.5	132.0	148.5
164	16.4	32.8	49.2	65.6	82.0	98.4	114.8	131.2	147.6
163	16.3	32.6	48.9	65.2	81.5	97.8	114.1	130.4	146.7
162	16.2	32.4	48.6	64.8	81.0	97.2	113.4	129.6	145.8
161	16.1	32.2	48.3	64.4	80.5	96.6	112.7	128.8	144.9

[No. 270 L. 431.] [No. 299 L. 476.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
270	431364	1525	1685	1846	2007	2167	2328	2488	2649	2809	161
1	2969	3130	3290	3450	3610	3770	3930	4090	4249	4409	160
2	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
3	6163	6322	6481	6640	6799	6957	7116	7275	7433	7592	159
4	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
5	9333	9491	9648	9806	9964	0122	0279	0437	0594	0752	158
6	440909	1066	1224	1381	1538	1695	1852	2009	2166	2323	157
7	2480	2637	2793	2950	3106	3263	3419	3576	3732	3889	157
8	4045	4201	4357	4513	4669	4825	4981	5137	5293	5449	156
9	5604	5760	5915	6071	6226	6382	6537	6692	6848	7003	155
280	7158	7313	7468	7623	7778	7933	8088	8242	8397	8552	155
1	8706	8861	9015	9170	9324	9478	9633	9787	9941	0095	154
2	450249	0403	0557	0711	0865	1018	1172	1326	1479	1633	154
3	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
4	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
5	4845	4997	5150	5302	5454	5606	5758	5910	6062	6214	152
6	6366	6518	6670	6821	6973	7125	7276	7428	7579	7731	152
7	7882	8033	8184	8336	8487	8638	8789	8940	9091	9242	151
8	9392	9543	9694	9845	9995	0146	0296	0447	0597	0748	151
9	460898	1048	1198	1348	1499	1649	1799	1948	2098	2248	150
290	2398	2548	2697	2847	2997	3146	3296	3445	3594	3744	150
1	3893	4042	4191	4340	4490	4639	4788	4936	5085	5234	149
2	5383	5532	5680	5829	5977	6126	6274	6423	6571	6719	149
3	6868	7016	7164	7312	7460	7608	7756	7904	8052	8200	148
4	8347	8495	8643	8790	8938	9085	9233	9380	9527	9675	148
5	9822	9969	0116	0263	0410	0557	0704	0851	0998	1145	147
6	471292	1438	1585	1732	1878	2025	2171	2318	2464	2610	146
7	2756	2903	3049	3195	3341	3487	3633	3779	3925	4071	146
8	4216	4362	4508	4653	4799	4944	5090	5235	5381	5526	146
9	5671	5816	5962	6107	6252	6397	6542	6687	6832	6976	145

PROPORTIONAL PARTS.

Di						6	7	8	9
161	16.1	32.2	48.3	64.4	80.5	96.6	112.7	128.8	144.9
160	16.0	32.0	48.0	64.0	80.0	96.0	112.0	128.0	144.0
159	15.9	31.8	47.7	63.6	79.5	95.4	111.3	127.2	143.1
158	15.8	31.6	47.4	63.2	79.0	94.8	110.6	126.4	142.2
157	15.7	31.4	47.1	62.8	78.5	94.2	109.9	125.6	141.3
156	15.6	31.2	46.8	62.4	78.0	93.6	109.2	124.8	140.4
155	15.5	31.0	46.5	62.0	77.5	93.0	108.5	124.0	139.5
154	15.4	30.8	46.2	61.6	77.0	92.4	107.8	123.2	138.6
153	15.3	30.6	45.9	61.2	76.5	91.8	107.1	122.4	137.7
152	15.2	30.4	45.6	60.8	76.0	91.2	106.4	121.6	136.8
151	15.1	30.2	45.3	60.4	75.5	90.6	105.7	120.8	135.9
150	15.0	30.0	45.0	60.0	75.0	90.0	105.0	120.0	135.0
149	14.9	29.8	44.7	59.6	74.5	89.4	104.3	119.2	134.1
148	14.8	29.6	44.4	59.2	74.0	88.8	103.6	118.4	133.2
147	14.7	29.4	44.1	58.8	73.5	88.2	102.9	117.6	132.3
146	14.6	29.2	43.8	58.4	73.0	87.6	102.2	116.8	131.4
145	14.5	29.0	43.5	58.0	72.5	87.0	101.5	116.0	130.5
144	14.4	28.8	43.2	57.6	72.0	86.4	100.8	115.2	129.6
143	14.3	28.6	42.9	57.2	71.5	85.8	100.1	114.4	128.7
142	14.2	28.4	42.6	56.8	71.0	85.2	99.4	113.6	127.8
141	14.1	28.2	42.3	56.4	70.5	84.6	98.7	112.8	126.9
140	14.0	28.0	42.0	56.0	70.0	84.0	98.0	112.0	126.0

No. 300 L. 477.] [No. 339 L. 531.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
300	477121	7266	7411	7555	7700	7844	7989	8133	8278	8422	145
1	8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
2	480007	0151	0294	0438	0582	0725	0869	1012	1156	1299	144
3	1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
4	2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
5	4300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
6	5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
7	7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
8	8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
9	9958										
		0099	0239	0380	0520	0661	0801	0941	1081	1222	140
310	491362	1502	1642	1782	1922	2062	2201	2341	2481	2621	140
1	2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
2	4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
3	5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
4	6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
5	8311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
6	9687	9824	9962								
				0099	0236	0374	0511	0648	0785	0922	137
7	501059	1196	1333	1470	1607	1744	1880	2017	2154	2291	137
8	2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
9	3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
320	5150	5286	5421	5557	5693	5828	5964	6099	6234	6370	136
1	6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
2	7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
3	9203	9337	9471	9606	9740	9874					
							0009	0143	0277	0411	134
4	510545	0679	0813	0947	1081	1215	1349	1482	1616	1750	134
5	1883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
6	3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
7	4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
8	5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
9	7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
330	8514	8646	8777	8909	9040	9171	9303	9434	9566	9697	131
1	9828	9959									
			0090	0221	0353	0484	0615	0745	0876	1007	131
2	521138	1269	1400	1530	1661	1792	1922	2053	2183	2314	131
3	2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
4	3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
5	5045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
6	6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
7	7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
8	8917	9045	9174	9302	9430	9559	9687	9815	9943		
										0072	128
9	530200	0328	0456	0584	0712	0840	0968	1096	1223	1351	128

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
139	13.9	27.8	41.7	55.6	69.5	83.4	97.3	111.2	125.1
138	13.8	27.6	41.4	55.2	69.0	82.8	96.6	110.4	124.2
137	13.7	27.4	41.1	54.8	68.5	82.2	95.9	109.6	123.3
136	13.6	27.2	40.8	54.4	68.0	81.6	95.2	108.8	122.4
135	13.5	27.0	40.5	54.0	67.5	81.0	94.5	108.0	121.5
134	13.4	26.8	40.2	53.6	67.0	80.4	93.8	107.2	120.6
133	13.3	26.6	39.9	53.2	66.5	79.8	93.1	106.4	119.7
132	13.2	26.4	39.6	52.8	66.0	79.2	92.4	105.6	118.8
131	13.1	26.2	39.3	52.4	65.5	78.6	91.7	104.8	117.9
130	13.0	26.0	39.0	52.0	65.0	78.0	91.0	104.0	117.0
129	12.9	25.8	38.7	51.6	64.5	77.4	90.3	103.2	116.1
128	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	115.2
127	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.6	114.3

N.	0	1	2	3	4	5	6	7	8	9	Diff.
340	531479	1607	1734	1862	1990	2117	2245	2372	2500	2627	128
1	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
2	4026	4153	4280	4407	4534	4661	4787	4914	5041	5167	127
3	5294	5421	5547	5674	5800	5927	6053	6180	6306	6432	126
4	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
5	7819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
6	9076	9202	9327	9452	9578	9703	9829	9954	0079	0204	125
7	540329	0455	0580	0705	0830	0955	1080	1205	1330	1454	125
8	1579	1704	1829	1953	2078	2203	2327	2452	2576	2701	125
9	2825	2950	3074	3199	3323	3447	3571	3696	3820	3944	124
350	4068	4192	4316	4440	4564	4688	4812	4936	5060	5183	124
1	5307	5431	5555	5678	5802	5925	6049	6172	6296	6419	124
2	6543	6666	6789	6913	7036	7159	7282	7405	7529	7652	123
3	7775	7898	8021	8144	8267	8389	8512	8635	8758	8881	123
4	9003	9126	9249	9371	9494	9616	9739	9861	9984	0106	123
5	550228	0351	0473	0595	0717	0840	0962	1084	1206	1328	122
6	1450	1572	1694	1816	1938	2060	2181	2303	2425	2547	122
7	2668	2790	2911	3033	3155	3276	3398	3519	3640	3762	121
8	3883	4004	4126	4247	4368	4489	4610	4731	4852	4973	121
9	5094	5215	5336	5457	5578	5699	5820	5940	6061	6182	121
360	6303	6423	6544	6664	6785	6905	7026	7146	7267	7387	120
1	7507	7627	7748	7868	7988	8108	8228	8349	8469	8589	120
2	8709	8829	8948	9068	9188	9308	9428	9548	9667	9787	120
3	9907	0026	0146	0265	0385	0504	0624	0743	0863	0982	119
4	561101	1221	1340	1459	1578	1698	1817	1936	2055	2174	119
5	2293	2412	2531	2650	2769	2887	3006	3125	3244	3362	119
6	3481	3600	3718	3837	3955	4074	4192	4311	4429	4548	119
7	4666	4784	4903	5021	5139	5257	5376	5494	5612	5730	118
8	5848	5966	6084	6202	6320	6437	6555	6673	6791	6909	118
9	7026	7144	7262	7379	7497	7614	7732	7849	7967	8084	118
370	8202	8319	8436	8554	8671	8788	8905	9023	9140	9257	117
1	9374	9491	9608	9725	9842	9959	0076	0193	0309	0426	117
2	570543	0660	0776	0893	1010	1126	1243	1359	1476	1592	117
3	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
4	2872	2988	3104	3220	3336	3452	3568	3684	3800	3915	116
5	4031	4147	4263	4379	4494	4610	4726	4841	4957	5072	116
6	5188	5303	5419	5534	5650	5765	5880	5996	6111	6226	115
7	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
8	7492	7607	7722	7836	7951	8066	8181	8295	8410	8525	115
9	8639	8754	8868	8983	9097	9212	9326	9441	9555	9669	114

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
128	12.8	25.6	38.4	51.2	64.0	76.8	89.6	102.4	115.2
127	12.7	25.4	38.1	50.8	63.5	76.2	88.9	101.6	114.3
126	12.6	25.2	37.8	50.4	63.0	75.6	88.2	100.8	113.4
125	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5
124	12.4	24.8	37.2	49.6	62.0	74.4	86.8	99.2	111.6
123	12.3	24.6	36.9	49.2	61.5	73.8	86.1	98.4	110.7
122	12.2	24.4	36.6	48.8	61.0	73.2	85.4	97.6	109.8
121	12.1	24.2	36.3	48.4	60.5	72.6	84.7	96.8	108.9
120	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108.0
119	11.9	23.8	35.7	47.6	59.5	71.4	83.3	95.2	107.1

No. 380. L. 579.] [No. 414 L. 617.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
380	579784	9898	0012	0126	0241	0355	0469	0583	0697	0811	114
1	580925	1039	1153	1267	1381	1495	1608	1722	1836	1950	
2	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	
3	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	
4	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
5	5461	5574	5686	5799	5912	6024	6137	6250	6362	6475	
6	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	
7	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
8	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	
9	9950	0061	0173	0284	0396	0507	0619	0730	0842	0953	
390	591065	1176	1287	1399	1510	1621	1732	1843	1955	2066	
1	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
2	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	
3	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	
4	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	
5	6597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
6	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	
7	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	
8	9883	9992	0101	0210	0319	0428	0537	0646	0755	0864	109
9	600973	1082	1191	1299	1408	1517	1625	1734	1843	1951	
400	2060	2169	2277	2386	2494	2603	2711	2819	2928	3036	
1	3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
2	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	
3	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	
4	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	
5	7455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
6	8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	
7	9594	9701	9808	9914	0021	0128	0234	0341	0447	0554	
8	610660	0767	0873	0979	1086	1192	1298	1405	1511	1617	
9	1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
410	2784	2890	2996	3102	3207	3313	3419	3525	3630	3736	
1	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	
2	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	
3	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
4	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
118	11.8	23.6	35.4	47.2	59.0	70.8	82.6	94.4	106.2
117	11.7	23.4	35.1	46.8	58.5	70.2	81.9	93.6	105.3
116	11.6	23.2	34.8	46.4	58.0	69.6	81.2	92.8	104.4
115	11.5	23.0	34.5	46.0	57.5	69.0	80.5	92.0	103.5
114	11.4	22.8	34.2	45.6	57.0	68.4	79.8	91.2	102.6
113	11.3	22.6	33.9	45.2	56.5	67.8	79.1	90.4	101.7
112	11.2	22.4	33.6	44.8	56.0	67.2	78.4	89.6	100.8
111	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	99.9
110	11.0	22.0	33.0	44.0	55.0	66.0	77.0	88.0	99.0
109	10.9	21.8	32.7	43.6	54.5	65.4	76.3	87.2	98.1
108	10.8	21.6	32.4	43.2	54.0	64.8	75.6	86.4	97.2
107	10.7	21.4	32.1	42.8	53.5	64.2	74.9	85.6	96.3
106	10.6	21.2	31.8	42.4	53.0	63.6	74.2	84.8	95.4
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94.5
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94.5
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2	93.6

No. 415 L. 618.] [No. 459 L. 662.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
415	618048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
6	9093	9198	9302	9406	9511	9615	9719	9824	9928	0032	
7	620136	0240	0344	0448	0552	0656	0760	0864	0968	1072	104
8	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	
9	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	
420	3249	3353	3456	3559	3663	3766	3869	3973	4076	4179	
1	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	103
2	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	
3	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	
4	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	
5	8389	8491	8593	8695	8797	8900	9002	9104	9206	9308	102
6	9410	9512	9613	9715	9817	9919	0021	0123	0224	0326	
7	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	
8	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	
9	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	
430	3468	3569	3670	3771	3872	3973	4074	4175	4276	4376	101
1	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	
2	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	
3	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	
4	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	100
5	8489	8589	8689	8789	8888	8988	9088	9188	9287	9387	
6	9486	9586	9686	9785	9885	9984	0084	0183	0283	0382	
7	640481	0581	0680	0779	0879	0978	1077	1177	1276	1375	
8	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	
9	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	99
440	3453	3551	3650	3749	3847	3946	4044	4143	4242	4340	
1	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	
2	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	
3	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	98
4	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	
5	8360	8458	8555	8653	8750	8848	8945	9043	9140	9237	
6	9335	9432	9530	9627	9724	9821	9919	0016	0113	0210	
7	650308	0405	0502	0599	0696	0793	0890	0987	1084	1181	
8	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	97
9	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	
450	3213	3309	3405	3502	3598	3695	3791	3888	3984	4080	
1	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	
2	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	96
3	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	
4	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	
5	8011	8107	8202	8298	8393	8488	8584	8679	8774	8870	
6	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	
7	9916	0011	0106	0201	0296	0391	0486	0581	0676	0771	95
8	660865	0960	1055	1150	1245	1339	1434	1529	1623	1718	
9	1813	1907	2002	2096	2191	2286	2380	2475	2569	2663	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
105	10.5	21.0	31.5	42.0	52.5	63.0	73.5	84.0	94.5
104	10.4	20.8	31.2	41.6	52.0	62.4	72.8	83.2	93.6
103	10.3	20.6	30.9	41.2	51.5	61.8	72.1	82.4	92.7
102	10.2	20.4	30.6	40.8	51.0	61.2	71.4	81.6	91.8
101	10.1	20.2	30.3	40.4	50.5	60.6	70.7	80.8	90.9
100	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
99	9.9	19.8	29.7	39.6	49.5	59.4	69.3	79.2	89.1

No. 460 L. 662.] [No. 499 L. 698.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	
1	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	
2	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
3	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	
4	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	
5	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	
6	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	
7	9317	9410	9503	9596	9689	9782	9875	9967	0060	0153	93
8	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	
9	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	
470	2098	2190	2283	2375	2467	2560	2652	2744	2836	2929	
1	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	
2	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
3	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	
4	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	
5	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	
6	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	
7	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
8	9428	9519	9610	9700	9791	9882	9973	0063	0154	0245	
9	680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	
480	1241	1332	1422	1513	1603	1693	1784	1874	1964	2055	
1	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	
2	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	
4	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	
5	5742	5831	5921	6010	6100	6189	6279	6368	6458	6547	
6	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	
7	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	
9	9309	9398	9486	9575	9664	9753	9841	9930	0019	0107	
490	690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	
1	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	
2	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	
3	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
4	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	
5	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	
6	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	
7	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	
8	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	
9	8100	8188	8275	8362	8449	8535	8622	8709	8796	8883	87

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
98	9.8	19.6	29.4	39.2	49.0	58.8	68.6	78.4	88.2
97	9.7	19.4	29.1	38.8	48.5	58.2	67.9	77.6	87.3
96	9.6	19.2	28.8	38.4	48.0	57.6	67.2	76.8	86.4
95	9.5	19.0	28.5	38.0	47.5	57.0	66.5	76.0	85.5
94	9.4	18.8	28.2	37.6	47.0	56.4	65.8	75.2	84.6
93	9.3	18.6	27.9	37.2	46.5	55.8	65.1	74.4	83.7
92	9.2	18.4	27.6	36.8	46.0	55.2	64.4	73.6	82.8
91	9.1	18.2	27.3	36.4	45.5	54.6	63.7	72.8	81.9
90	9.0	18.0	27.0	36.0	45.0	54.0	63.0	72.0	81.0
89	8.9	17.8	26.7	35.6	44.5	53.4	62.3	71.2	80.1
88	8.8	17.6	26.4	35.2	44.0	52.8	61.6	70.4	79.2
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4

No. 500 L. 698.] [No. 544 L. 736.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
500	698970	9057	9144	9231	9317	9404	9491	9578	9664	9751	
1	9838	9924	0011	0098	0184	0271	0358	0444	0531	0617	
2	700704	0790	0877	0963	1050	1136	1222	1309	1395	1482	
3	1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	
4	2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	
5	3291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
6	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	
7	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	
8	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	
9	6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	
510	7570	7655	7740	7826	7911	7996	8081	8166	8251	8336	85
1	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	
2	9270	9355	9440	9524	9609	9694	9779	9863	9948	0033	
3	710117	0202	0287	0371	0456	0540	0625	0710	0794	0879	
4	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	
5	1807	1892	1976	2060	2144	2229	2313	2397	2481	2566	
6	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	
7	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
8	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	
9	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	
520	6003	6087	6170	6254	6337	6421	6504	6588	6671	6754	
1	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	
2	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	
3	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
4	9331	9414	9497	9580	9663	9745	9828	9911	9994	0077	
5	720159	0242	0325	0407	0490	0573	0655	0738	0821	0903	
6	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	
7	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	
8	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	
9	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	4276	4358	4440	4522	4604	4685	4767	4849	4931	5013	
1	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	
2	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	
3	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	
4	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	
5	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	
6	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
7	9974	0055	0136	0217	0298	0378	0459	0540	0621	0702	
8	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	
9	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	
540	2394	2474	2555	2635	2715	2796	2876	2956	3037	3117	
1	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	
2	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	80
3	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	
4	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4
85	8.5	17.0	25.5	34.0	42.5	51.0	59.5	68.0	76.5
84	8.4	16.8	25.2	33.6	42.0	50.4	58.8	67.2	75.6

No. 460 L. 662.] [No. 499 L. 698.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	
1	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	
2	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
3	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	
4	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	
5	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	
6	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	
7	9317	9410	9503	9596	9689	9782	9875	9967	0060	0153	93
8	670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	
9	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	
470	2098	2190	2283	2375	2467	2560	2652	2744	2836	2929	
1	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	
2	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
3	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	
4	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	
5	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	
6	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	
7	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
8	9428	9519	9610	9700	9791	9882	9973	0063	0154	0245	
9	680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	
480	1241	1332	1422	1513	1603	1693	1784	1874	1964	2055	
1	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	
2	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	
4	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	
5	5742	5831	5921	6010	6100	6189	6279	6368	6458	6547	
6	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	
7	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	
9	9309	9398	9486	9575	9664	9753	9841	9930	0019	0107	
490	690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	
1	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	
2	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	
3	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
4	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	
5	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	
6	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	
7	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	
8	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	
9	8100	8188	8275	8362	8449	8535	8622	8709	8796	8883	87

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
98	9.8	19.6	29.4	39.2	49.0	58.8	68.6	78.4	88.2
97	9.7	19.4	29.1	38.8	48.5	58.2	67.9	77.6	87.3
96	9.6	19.2	28.8	38.4	48.0	57.6	67.2	76.8	86.4
95	9.5	19.0	28.5	38.0	47.5	57.0	66.5	76.0	85.5
94	9.4	18.8	28.2	37.6	47.0	56.4	65.8	75.2	84.6
93	9.3	18.6	27.9	37.2	46.5	55.8	65.1	74.4	83.7
92	9.2	18.4	27.6	36.8	46.0	55.2	64.4	73.6	82.8
91	9.1	18.2	27.3	36.4	45.5	54.6	63.7	72.8	81.9
90	9.0	18.0	27.0	36.0	45.0	54.0	63.0	72.0	81.0
89	8.9	17.8	26.7	35.6	44.5	53.4	62.3	71.2	80.1
88	8.8	17.6	26.4	35.2	44.0	52.8	61.6	70.4	79.2
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4

No. 500 L. 698.] [No. 544 L. 736.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
500	698970	9057	9144	9231	9317	9404	9491	9578	9664	9751	
1	9838	9924	0011	0098	0184	0271	0358	0444	0531	0617	
2	700704	0790	0877	0963	1050	1136	1222	1309	1395	1482	
3	1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	
4	2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	
5	3291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
6	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	
7	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	
8	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	
9	6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	
510	7570	7655	7740	7826	7911	7996	8081	8166	8251	8336	85
1	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	
2	9270	9355	9440	9524	9609	9694	9779	9863	9948	0033	
3	710117	0202	0287	0371	0456	0540	0625	0710	0794	0879	
4	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	
5	1807	1892	1976	2060	2144	2229	2313	2397	2481	2566	
6	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	
7	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
8	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	
9	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	
520	6003	6087	6170	6254	6337	6421	6504	6588	6671	6754	
1	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	
2	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	
3	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
4	9331	9414	9497	9580	9663	9745	9828	9911	9994	0077	
5	720159	0242	0325	0407	0490	0573	0655	0738	0821	0903	
6	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	
7	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	
8	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	
9	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	4276	4358	4440	4522	4604	4685	4767	4849	4931	5013	
1	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	
2	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	
3	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	
4	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	
5	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	
6	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
7	9974	0055	0136	0217	0298	0378	0459	0540	0621	0702	
8	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	
9	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	
540	2394	2474	2555	2635	2715	2796	2876	2956	3037	3117	
1	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	
2	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	
3	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
4	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
87	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
86	8.6	17.2	25.8	34.4	43.0	51.6	60.2	68.8	77.4
85	8.5	17.0	25.5	34.0	42.5	51.0	59.5	68.0	76.5
84	8.4	16.8	25.2	33.6	42.0	50.4	58.8	67.2	75.6

No. 545 L. 736.]										[No. 584 L. 767.	
N.	0	1	2	3	4	5	6	7	8	9	Diff.
545	736397	6476	6556	6635	6715	6795	6874	6954	7034	7113	
6	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	
7	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	
8	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	
9	9572	9651	9731	9810	9889	9968					
							0047	0126	0205	0284	79
550	740363	0442	0521	0600	0678	0757	0836	0915	0994	1073	
1	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	
2	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	
3	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	
4	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	
5	4293	4371	4449	4528	4606	4684	4762	4840	4919	4997	
6	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
7	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	
8	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	
9	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	
560	8188	8266	8343	8421	8498	8576	8653	8731	8808	8885	
1	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	
2	9736	9814	9891	9968							
					0045	0123	0200	0277	0354	0431	
3	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	
4	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	
5	2048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
6	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	
7	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	
8	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	
9	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	
570	5875	5951	6027	6103	6180	6256	6332	6408	6484	6560	
1	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
2	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	
3	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	
4	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	
5	9668	9743	9819	9894	9970						
						0045	0121	0196	0272	0347	
6	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	
7	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	
8	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	
9	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	75
580	3428	3503	3578	3653	3727	3802	3877	3952	4027	4101	
1	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	
2	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	
3	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	
4	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
83	8.3	16.6	24.9	33.2	41.5	49.8	58.1	66.4	74.7
82	8.2	16.4	24.6	32.8	41.0	49.2	57.4	65.6	73.8
81	8.1	16.2	24.3	32.4	40.5	48.6	56.7	64.8	72.9
80	8.0	16.0	24.0	32.0	40.0	48.0	56.0	64.0	72.0
79	7.9	15.8	23.7	31.6	39.5	47.4	55.3	63.2	71.1
78	7.8	15.6	23.4	31.2	39.0	46.8	54.6	62.4	70.2
77	7.7	15.4	23.1	30.8	38.5	46.2	53.9	61.6	69.3
76	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
74	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6

No. 585 L. 767.] [No. 629 L. 799.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
585	767156	7230	7304	7379	7453	7527	7601	7675	7749	7823	
6	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
7	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	
8	9377	9451	9525	9599	9673	9746	9820	9894	9968	0042	
9	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	
590	0852	0926	0999	1073	1146	1220	1293	1367	1440	1514	
1	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	
2	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	
3	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	
4	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
5	4517	4590	4663	4736	4809	4882	4955	5028	5100	5173	
6	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	
7	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	
8	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	
9	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	
600	8151	8224	8296	8368	8441	8513	8585	8658	8730	8802	
1	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	
2	9596	9669	9741	9813	9885	9957	0029	0101	0173	9245	72
3	780317	0389	0461	0533	0605	0677	0749	0821	0893	0965	
4	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	
5	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	
6	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	
7	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	
8	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	
9	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	
610	5330	5401	5472	5543	5615	5686	5757	5828	5899	5970	
1	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	71
2	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	
3	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	
4	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	
5	8875	8946	9016	9087	9157	9228	9299	9369	9440	9510	
6	9581	9651	9722	9792	9863	9933	0004	0074	0144	0215	
7	790285	0356	0426	0496	0567	0637	0707	0778	0848	0918	
8	0988	1059	1129	1199	1269	1340	1410	1480	1550	1620	
9	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	
620	2392	2462	2532	2602	2672	2742	2812	2882	2952	3022	70
1	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	
2	3790	3860	3930	4000	4070	4139	4209	4279	4349	4418	
3	4488	4558	4627	4697	4767	4836	4906	4976	5045	5115	
4	5185	5254	5324	5393	5463	5532	5602	5672	5741	5811	
5	5880	5949	6019	6088	6158	6227	6297	6366	6436	6505	
6	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	
7	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	
8	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	
9	8651	8720	8789	8858	8927	8996	9065	9134	9203	9272	69

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
75	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5
74	7.4	14.8	22.2	29.6	37.0	44.4	51.8	59.2	66.6
73	7.3	14.6	21.9	29.2	36.5	43.8	51.1	58.4	65.7
72	7.2	14.4	21.6	28.8	36.0	43.2	50.4	57.6	64.8
71	7.1	14.2	21.3	28.4	35.5	42.6	49.7	56.8	63.9
70	7.0	14.0	21.0	28.0	35.0	42.0	49.0	56.0	63.0
69	6.9	13.8	20.7	27.6	34.5	41.4	48.3	55.2	62.1

No. 630 L. 799.] [No. 674 L. 829.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
630	799341	9409	9478	9547	9616	9685	9754	9823	9892	9961	
1	800029	0098	0167	0236	0305	0373	0442	0511	0580	0648	
2	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	
3	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	
4	2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	
5	2774	2842	2910	2979	3047	3116	3184	3252	3321	3389	
6	3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	
7	4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	
8	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
9	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	
640	806180	6248	6316	6384	6451	6519	6587	6655	6723	6790	
1	6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	
2	7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	
3	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	
4	8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	
5	9560	9627	9694	9762	9829	9896	9964	0031	0098	0165	
6	810233	0300	0367	0434	0501	0569	0636	0703	0770	0837	
7	0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
8	1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	
9	2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	
650	2913	2980	3047	3114	3181	3247	3314	3381	3448	3514	
1	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	
2	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	
3	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	
4	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	
5	6241	6308	6374	6440	6506	6573	6639	6705	6771	6838	
6	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	
7	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	
8	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	
9	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	9544	9610	9676	9741	9807	9873	9939	0004	0070	0136	
1	820201	0267	0333	0399	0464	0530	0595	0661	0727	0792	
2	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	
3	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	
4	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	
5	2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	
6	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	
7	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	
8	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
9	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	
670	6075	6140	6204	6269	6334	6399	6464	6528	6593	6658	
1	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	
2	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	
3	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	
4	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
68	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4	61.2
67	6.7	13.4	20.1	26.8	33.5	40.2	46.9	53.6	60.3
66	6.6	13.2	19.8	26.4	33.0	39.6	46.2	52.8	59.4
65	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5
64	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6

N.	0	1	2	3	4	5	6	7	8	9	Diff.
675	829304	9368	9432	9497	9561	9625	9690	9754	9818	9882	
6	9947	0011	0075	0139	0204	0268	0332	0396	0460	0525	
7	830589	0653	0717	0781	0845	0909	0973	1037	1102	1166	
8	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
9	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	
680	2509	2573	2637	2700	2764	2828	2892	2956	3020	3083	
1	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	
2	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	
3	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	
4	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	
5	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	
6	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	
7	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	
8	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	
9	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	8849	8912	8975	9038	9101	9164	9227	9289	9352	9415	
1	9478	9541	9604	9667	9729	9792	9855	9918	9981	0043	
2	840106	0169	0232	0294	0357	0420	0482	0545	0608	0671	
3	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	
4	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	
5	1985	2047	2110	2172	2235	2297	2360	2422	2484	2547	
6	2609	2672	2734	2796	2859	2921	2983	3046	3108	3170	
7	3233	3295	3357	3420	3482	3544	3606	3669	3731	3793	
8	3855	3918	3980	4042	4104	4166	4229	4291	4353	4415	
9	4477	4539	4601	4664	4726	4788	4850	4912	4974	5036	
700	5098	5160	5222	5284	5346	5408	5470	5532	5594	5656	62
1	5718	5780	5842	5904	5966	6028	6090	6151	6213	6275	
2	6337	6399	6461	6523	6585	6646	6708	6770	6832	6894	
3	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	
4	7573	7634	7696	7758	7819	7881	7943	8004	8066	8128	
5	8189	8251	8312	8374	8435	8497	8559	8620	8682	8743	
6	8805	8866	8928	8989	9051	9112	9174	9235	9297	9358	
7	9419	9481	9542	9604	9665	9726	9788	9849	9911	9972	
8	850033	0095	0156	0217	0279	0340	0401	0462	0524	0585	
9	0646	0707	0769	0830	0891	0952	1014	1075	1136	1197	
710	1258	1320	1381	1442	1503	1564	1625	1686	1747	1809	
1	1870	1931	1992	2053	2114	2175	2236	2297	2358	2419	
2	2480	2541	2602	2663	2724	2785	2846	2907	2968	3029	61
3	3090	3150	3211	3272	3333	3394	3455	3516	3577	3637	
4	3698	3759	3820	3881	3941	4002	4063	4124	4185	4245	
5	4306	4367	4428	4488	4549	4610	4670	4731	4792	4852	
6	4913	4974	5034	5095	5156	5216	5277	5337	5398	5459	
7	5519	5580	5640	5701	5761	5822	5882	5943	6003	6064	
8	6124	6185	6245	6306	6366	6427	6487	6548	6608	6668	
9	6729	6789	6850	6910	6970	7031	7091	7152	7212	7272	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
65	6.5	13.0	19.5	26.0	32.5	39.0	45.5	52.0	58.5
64	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6
63	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7
62	6.2	12.4	18.6	24.8	31.0	37.2	43.4	49.6	55.8
61	6.1	12.2	18.3	24.4	30.5	36.6	42.7	48.8	54.9
60	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0

No. 720 L. 857.] [No. 764 L. 883.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
720	857332	7393	7453	7513	7574	7634	7694	7755	7815	7875	
1	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	
2	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	
3	9138	9198	9258	9318	9379	9439	9499	9559	9619	9679	60
4	9739	9799	9859	9918	9978	0038	0098	0158	0218	0278	
5	860338	0398	0458	0518	0578	0637	0697	0757	0817	0877	
6	0937	0996	1056	1116	1176	1236	1295	1355	1415	1475	
7	1534	1594	1654	1714	1773	1833	1893	1952	2012	2072	
8	2131	2191	2251	2310	2370	2430	2489	2549	2608	2668	
9	2728	2787	2847	2906	2966	3025	3085	3144	3204	3263	
730	3323	3382	3442	3501	3561	3620	3680	3739	3799	3858	
1	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	
2	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	
3	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	
4	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	
5	6287	6346	6405	6465	6524	6583	6642	6701	6760	6819	
6	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	59
7	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	
8	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	
9	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	
740	9232	9290	9349	9408	9466	9525	9584	9642	9701	9760	
1	9818	9877	9935	9994	0053	0111	0170	0228	0287	0345	
2	870404	0462	0521	0579	0638	0696	0755	0813	0872	0930	
3	0989	1047	1106	1164	1223	1281	1339	1398	1456	1515	
4	1573	1631	1690	1748	1806	1865	1923	1981	2040	2098	
5	2156	2215	2273	2331	2389	2448	2506	2564	2622	2681	
6	2739	2797	2855	2913	2972	3030	3088	3146	3204	3262	
7	3321	3379	3437	3495	3553	3611	3669	3727	3785	3844	
8	3902	3960	4018	4076	4134	4192	4250	4308	4366	4424	58
9	4482	4540	4598	4656	4714	4772	4830	4888	4945	5003	
750	5061	5119	5177	5235	5293	5351	5409	5466	5524	5582	
1	5640	5698	5756	5813	5871	5929	5987	6045	6102	6160	
2	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	
3	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	
4	7371	7429	7487	7544	7602	7659	7717	7774	7832	7889	
5	7947	8004	8062	8119	8177	8234	8292	8349	8407	8464	
6	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	
7	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	
8	9669	9726	9784	9841	9898	9956	0013	0070	0127	0185	
9	880242	0299	0356	0413	0471	0528	0585	0642	0699	0756	
760	0814	0871	0928	0985	1042	1099	1156	1213	1271	1328	
1	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	
2	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
3	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	
4	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
59	5.9	11.8	17.7	23.6	29.5	35.4	41.3	47.2	53.1
58	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.2
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4

No. 765 L. 883.] [No. 809 L. 908.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	
6	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	
7	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	
8	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	
9	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	
770	6491	6547	6604	6660	6716	6773	6829	6885	6942	6998	
1	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	
2	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	
3	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	
4	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	
5	9302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
6	9862	9918	9974	0030	0086	0141	0197	0253	0309	0365	
7	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	
8	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	
9	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	
780	2095	2150	2206	2262	2317	2373	2429	2484	2540	2595	
1	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	
2	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	
3	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	
4	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	
5	4870	4925	4980	5036	5091	5146	5201	5257	5312	5367	
6	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	
7	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	
8	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	
9	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	
790	7627	7682	7737	7792	7847	7902	7957	8012	8067	8122	55
1	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	
2	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	
3	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	
4	9821	9875	9930	9985	0039	0094	0149	0203	0258	0312	
5	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	
6	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	
7	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	
8	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	
9	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	
800	3090	3144	3199	3253	3307	3361	3416	3470	3524	3578	
1	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	
2	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	
3	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	54
4	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	
5	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	
6	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	
7	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	
8	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	
9	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
57	5.7	11.4	17.1	22.8	28.5	34.2	39.9	45.6	51.3
56	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.8	50.4
55	5.5	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5
54	5.4	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.6

No. 810 L. 908.] [No. 854 L. 931.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
810	908485	8539	8592	8646	8699	8753	8807	8860	8914	8967	
1	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	
2	9556	9610	9663	9716	9770	9823	9877	9930	9984	0037	
3	910091	0144	0197	0251	0304	0358	0411	0464	0518	0571	
4	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	
5	1158	1211	1264	1317	1371	1424	1477	1530	1584	1637	
6	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	
7	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	
8	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	
9	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
820	3814	3867	3920	3973	4026	4079	4132	4184	4237	4290	
1	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	
2	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	
3	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	
4	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	
5	6454	6507	6559	6612	6664	6717	6770	6822	6875	6927	
6	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	
7	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	
8	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	
9	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	
830	9078	9130	9183	9235	9287	9340	9392	9444	9496	9549	
1	9601	9653	9706	9758	9810	9862	9914	9967	0019	0071	
2	920123	0176	0228	0280	0332	0384	0436	0489	0541	0593	
3	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	
4	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
5	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	
6	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	
7	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	
8	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	
9	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	
840	4279	4331	4383	4434	4486	4538	4589	4641	4693	4744	
1	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	
2	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	
3	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	
4	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	
5	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	
6	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	
7	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	
8	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	
9	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	
850	9419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
1	9930	9981	0032	0083	0134	0185	0236	0287	0338	0389	
2	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	
3	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	
4	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	

Proportional Parts.

Diff.	1	2	3	4	5	6	7	8	9
53	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.7
52	5.2	10.4	15.6	20.8	26.0	31.2	36.4	41.6	46.8
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0

No. 855 L. 931.] [No. 899 L. 954.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
855	931966	2017	[illegible]	2118	2169	2220	2271	2322	2372	2423	
6	2474	2524	[illegible]	2626	2677	2727	2778	2829	2879	2930	
7	2981	3031	[illegible]	3133	3183	3234	3285	3335	3386	3437	
8	3487	3538	[illegible]	3639	3690	3740	3791	3841	3892	3943	
9	3993	4044	[illegible]	4145	4195	4246	4296	4347	4397	4448	
860	4498	4549	[illegible]	4650	4700	4751	4801	4852	4902	4953	
1	5003	5054	[illegible]	5154	5205	5255	5306	5356	5406	5457	
2	5507	5558	[illegible]	5658	5709	5759	5809	5860	5910	5960	
3	6011	6061	[illegible]	6162	6212	6262	6313	6363	6413	6463	
4	6514	6564	[illegible]	6665	6715	6765	6815	6865	6916	6966	
5	7016	7066	[illegible]	7167	7217	7267	7317	7367	7418	7468	
6	7518	7568	[illegible]	7668	7718	7769	7819	7869	7919	7969	
7	8019	8069	[illegible]	8169	8219	8269	8320	8370	8420	8470	50
8	8520	8570	[illegible]	8670	8720	8770	8820	8870	8920	8970	
9	9020	9070	[illegible]	9170	9220	9270	9320	9369	9419	9469	
870	9519	9569	[illegible]	9669	9719	9769	9819	9869	9918	9968	
1	940018	0068	0118	[illegible]	0218	0267	0317	0367	0417	0467	
2	0516	0566	0616	[illegible]	0716	0765	0815	0865	0915	0964	
3	1014	1064	1114	[illegible]	1213	1263	1313	1362	1412	1462	
4	1511	1561	1611	[illegible]	1710	1760	1809	1859	1909	1958	
5	2008	2058	2107	[illegible]	2207	2256	2306	2355	2405	2455	
6	2504	2554	2603	[illegible]	2702	2752	2801	2851	2901	2950	
7	3000	3049	3099	[illegible]	3198	3247	3297	3346	3396	3445	
8	3495	3544	3593	[illegible]	3692	3742	3791	3841	3890	3939	
9	3989	4038	4088	[illegible]	4186	4236	4285	4335	4384	4433	
880	4483	4532	4581	[illegible]	4680	4729	4779	4828	4877	4927	
1	4976	5025	5074	[illegible]	5173	5222	5272	5321	5370	5419	
2	5469	5518	5567	[illegible]	5665	5715	5764	5813	5862	5912	
3	5961	6010	6059	[illegible]	6157	6207	6256	6305	6354	6403	
4	6452	6501	6551	[illegible]	6649	6698	6747	6796	6845	6894	
5	6943	6992	7041	[illegible]	7140	7189	7238	7287	7336	7385	49
6	7434	7483	7532	[illegible]	7630	7679	7728	7777	7826	7875	
7	7924	7973	8022	[illegible]	8119	8168	8217	8266	8315	8364	
8	8413	8462	8511	[illegible]	8609	8657	8706	8755	8804	8853	
9	8902	8951	8999	[illegible]	9097	9146	9195	9244	9292	9341	
890	9390	9439	9488	[illegible]	9585	9634	9683	9731	9780	9829	
1	9878	9926	9975	0024	0073	0121	0170	0219	0267	0316	
2	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	
3	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	
4	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	
5	1823	1872	1920	1969	2017	2066	2114	2163	2211	2260	
6	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	
7	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	
8	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	
9	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
51	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9
50	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0
49	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1
48	4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2

No 900 L. 954.]										[No. 944 L. 975.
N.	0	1	2	3	4	5	6	7	8	9	Diff.
900	954243	4291	4339	4387	4435	4484	4532	4580	4628	4677	
1	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	
2	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	
3	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	
4	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	
5	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
6	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	
7	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	
8	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	
9	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	
910	9041	9089	9137	9185	9232	9280	9328	9375	9423	9471	
1	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	
2	9995										
		0042	0090	0138	0185	0233	0280	0328	0376	0423	
3	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	
4	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	
5	1421	1469	1516	1563	1611	1658	1706	1753	1801	1848	
6	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	
7	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	
8	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	
9	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	
920	3788	3835	3882	3929	3977	4024	4071	4118	4165	4212	
1	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	
2	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	
3	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	
4	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
5	6142	6189	6236	6283	6329	6376	6423	6470	6517	6564	
6	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	
7	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	
8	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	
9	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	
930	8483	8530	8576	8623	8670	8716	8763	8810	8856	8903	
1	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	
2	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	
3	9882	9928	9975								
				0021	0068	0114	0161	0207	0254	0300	
4	970347	0393	0440	0486	0533	0579	0626	0672	0719	0765	
5	0812	0858	0904	0951	0997	1044	1090	1137	1183	1229	
6	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	
7	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	
8	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	
9	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	
940	3128	3174	3220	3266	3313	3359	3405	3451	3497	3543	
1	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	
2	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	
3	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	
4	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
47	4.7	9.4	14.1	18.8	23.5	28.2	32.9	37.6	42.3
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4

No. 945 L. 975.] [No. 989 L. 995.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
945	975432	5478	5524	5570	5616	5662	5707	5753	5799	5845	
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	
950	7724	7769	7815	7861	7906	7952	7998	8043	8089	8135	
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	
5	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	
960	2271	2316	2362	2407	2452	2497	2543	2588	2633	2678	
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	
7	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	
970	6772	6817	6861	6906	6951	6996	7040	7085	7130	7175	
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	
7	9895	9939	9983	0028	0072	0117	0161	0206	0250	0294	
8	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	
980	1226	1270	1315	1359	1403	1448	1492	1536	1580	1625	
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	

PROPORTIONAL PARTS.

Diff.	1	2	3	4	5	6	7	8	9
46	4.6	9.2	13.8	18.4	23.0	27.6	32.2	36.8	41.4
45	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5
44	4.4	8.8	13.2	17.6	22.0	26.4	30.8	35.2	39.6
43	4.3	8.6	12.9	17.2	21.5	25.8	30.1	34.4	38.7

No. 990 L. 995.] [No. 999 L. 999.

N.	0	1	2	3	4	5	6	7	8	9	Diff.
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	
1	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
2	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	
3	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	
4	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	
5	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	
6	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	
7	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	
8	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	
9	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

CONSTANT NUMBERS AND THEIR LOGARITHMS.

Symbol.	Number.	Logarithm.
π	3.141 592 653 590	0.497 149 872 694
2π	6.283 185 307 180	0.798 179 868 358
3π	9.424 777 960 769	0.974 271 127 414
4π	12.566 370 614 359	1.099 209 864 022
5π	15.707 963 267 950	1.196 119 877 030
6π	18.849 555 921 539	1.275 301 123 078
7π	21.991 148 575 119	1.342 247 912 708
8π	25.132 741 228 718	1.400 239 859 686
9π	28.274 333 882 308	1.451 392 382 133
$\frac{1}{6}\pi$	0.523 598 775 598	$\bar{1}$.718 998 622 810
$\frac{1}{4}\pi$	0.785 398 163 397	$\bar{1}$.895 089 881 366
$\frac{1}{2}\pi$	1.570 796 326 795	0.196 119 877 030
$\frac{4}{3}\pi$	4.187 790 204 786	0.622 088 609 302
π^2	9.869 604 401 089	0.994 299 745 388
π^3	31.006 276 680 293	1.491 449 618 082
$\sqrt{\pi}$	1.772 453 850 906	0.248 574 936 347
$\sqrt[3]{\pi}$	1.464 591 887 562	0.165 716 624 231
$1/\pi$	0.318 309 886 184	$\bar{1}$.502 850 127 306
$180/\pi$	57.295 779 513 025	1.758 122 632 409
$1/\pi^2$	0.101 321 183 642	$\bar{1}$.005 700 254 612
$1/\sqrt{\pi}$	0.564 189 583 548	$\bar{1}$.751 425 063 653
$\log_e \pi$	1.144 729 885 849	0.058 703 021 240
arc 1°	0.017 453 292 520	$\bar{2}$.241 877 367 591
sin 1°	0.017 452 406 417	$\bar{2}$.241 855 318 418
arc 1′	0.000 290 888 209	$\bar{4}$.463 726 117 207
sin 1′	0.000 290 888 205	$\bar{4}$.463 726 111 082
arc 1″	0.000 004 848 137	$\bar{6}$.685 574 866 824
sin 1″	0.000 004 848 137	$\bar{6}$.685 574 866 822
e	2.718 281 828 459	0.434 294 481 903
M	0.434 294 481 903	$\bar{1}$.637 784 311 301
$1/M$	2.302 585 092 994	0.362 215 688 699
$\sqrt{2}$	1.414 213 562 373	0.150 514 997 832
$\sqrt{3}$	1.732 050 807 569	0.238 560 627 360
$\sqrt{5}$	2.236 067 977 477	0.349 485 002 168

TRIGONOMETRICAL FUNCTIONS.

Right-angled Triangles.

Let A (Fig. 1) = angle BAC = arc BF, and let the radius $AF = AB = AH = 1$.

We then have

$\sin A = BC$
$\cos A = AC$
$\tan A = DF$
$\cot A = HG$
$\sec A = AD$
$\operatorname{cosec} A = AG$
$\operatorname{versin} A = CF = BE$
$\operatorname{covers} A = BK = HL$
$\operatorname{exsec} A = BD$
$\operatorname{coexsec} A = BG$
$\operatorname{chord} A = BF$
$\operatorname{chord} 2A = BI = 2BC$

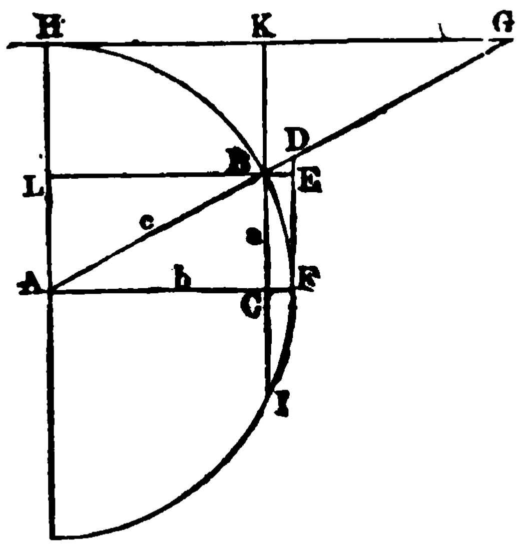

FIG. 1.

In the right-angled triangle ABC (Fig. 1)
Let $AB = c$, $AC = b$, and $BC = a$.
We then have:

1. $\sin A = \dfrac{a}{c} = \cos B$
2. $\cos A = \dfrac{b}{c} = \sin B$
3. $\tan A = \dfrac{a}{b} = \cot B$
4. $\cot A = \dfrac{b}{a} = \tan B$
5. $\sec A = \dfrac{c}{b} = \operatorname{cosec} B$
6. $\operatorname{cosec} A = \dfrac{c}{a} = \sec B$
7. $\operatorname{vers} A = \dfrac{c-b}{c} = \operatorname{covers} B$
8. $\operatorname{exsec} A = \dfrac{c-b}{b} = \operatorname{coexsec} B$
9. $\operatorname{covers} A = \dfrac{c-a}{c} = \operatorname{versin} B$
10. $\operatorname{coexsec} A = \dfrac{c-a}{a} = \operatorname{exsec} B$
11. $a = c \sin A = b \tan A$
12. $b = c \cos A = a \cot A$
13. $c = \dfrac{a}{\sin A} = \dfrac{b}{\cos A}$
14. $a = c \cos B = b \cot B$
15. $b = c \sin B = a \tan B$
16. $c = \dfrac{a}{\cos B} = \dfrac{b}{\sin B}$
17. $a = \sqrt{(c+b)(c-b)}$
18. $b = \sqrt{(c+a)(c-a)}$
19. $c = \sqrt{a^2 + b^2}$
20. $C = 90^\circ = A + B$

21. area $= \dfrac{ab}{2}$

Plane Triangles.

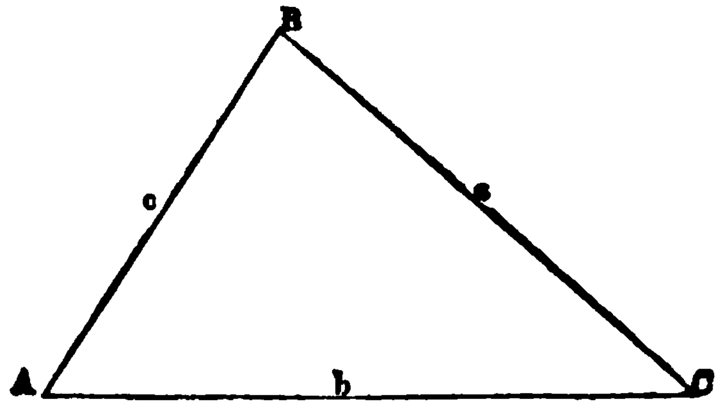

FIG. 2.

	GIVEN.	SOUGHT.	FORMULÆ.
22	A, B, a	C, b, c	$C = 180° - (A + B)$, $b = \frac{a}{\sin A} \cdot \sin B$, $c = \frac{a}{\sin A} \sin (A + B)$
23	A, a, b	B, C, c	$\sin B = \frac{\sin A}{a} \cdot b$, $C = 180° - (A + B)$, $c = \frac{a}{\sin A} \cdot \sin C$.
24	C, a, b	$\frac{1}{2}(A + B)$	$\frac{1}{2}(A + B) = 90° - \frac{1}{2} C$
25		$\frac{1}{2}(A - B)$	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
26		A, B	$A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$, $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$
27		c	$c = (a + b) \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} = (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$
28		area	$K = \frac{1}{2} a b \sin C$.
29	a, b, c	A	Let $s = \frac{1}{2}(a + b + c)$; $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$
30			$\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
31			$\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$; $\text{vers } A = \frac{2(s-b)(s-c)}{bc}$
32		area	$K = \sqrt{s(s-a)(s-b)(s-c)}$
33	A, B, C, a	area	$K = \frac{a^2 \sin B \cdot \sin C}{2 \sin A}$

Table 84.
SINES, COSINES, SECANTS, AND COSECANTS.

′	0° Sine	0° Cosin	1° Sine	1° Cosin	2° Sine	2° Cosin	3° Sine	3° Cosin	4° Sine	4° Cosin	′
0	.00000	One.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	One.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	One.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	One.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	One.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	One.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	One.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	One.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	One.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	One.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	One.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	89°		88°		87°		86°		85°		

′	5° Sine	5° Cosin	6° Sine	6° Cosin	7° Sine	7° Cosin	8° Sine	8° Cosin	9° Sine	9° Cosin	′
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	.19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
′	79°		78°		77°		76°		75°		′

′	15° Sine	15° Cosin	16° Sine	16° Cosin	17° Sine	17° Cosin	18° Sine	18° Cosin	19° Sine	19° Cosin	′
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95782	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95183	.32474	.93580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	74° Cosin	74° Sine	73° Cosin	73° Sine	72° Cosin	72° Sine	71° Cosin	71° Sine	70° Cosin	70° Sine	′

′	20°		21°		22°		23°		24°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	.87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	0
	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	
′	64°		63°		62°		61°		60°		′

′	30°		31°		32°		33°		34°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	.64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
′	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	Cosin	Sine	′
	54°		53°		52°		51°		50°		

′	40° Sine	40° Cosin	41° Sine	41° Cosin	42° Sine	42° Cosin	43° Sine	43° Cosin	44° Sine	44° Cosin	′
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	49° Cosin	49° Sine	48° Cosin	48° Sine	47° Cosin	47° Sine	46° Cosin	46° Sine	45° Cosin	45° Sine	′

Secants.

′							′
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8
53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
54	[illegible]	[illegible]	[illegible]	1			
55	[illegible]	[illegible]	[illegible]	1			
56	[illegible]	[illegible]	[illegible]	1			
57	[illegible]	[illegible]	[illegible]	1			
58	[illegible]	[illegible]	[illegible]	1			
59	[illegible]	[illegible]	[illegible]	1			
60	[illegible]	[illegible]	[illegible]	1			

SECANTS.

′	6°	7°	8°	9°	10°	11°	′
0	1·0055083	1·0075098	1·0098276	1·0124651	1·0154266	1·0187167	60
1	1·0055301	1·0075159	1·0098689	1·0125118	1·0154787	1·0187748	59
2	1·0055009	1·0075820	1·0099103	1·0125586	1·0155310	1·0188321	58
3	1·0056009	1·0076182	1·0099518	1·0126055	1·0155833	1·0188899	57
4	1·0056319	1·0076545	1·0099934	1·0126524	1·0156357	1·0189478	56
5	1·0056681	1·0076908	1·0100351	1·0126993	1·0156882	1·0190059	55
6	1·0056048	1·0077273	1·0100769	1·0127466	1·0157408	1·0190640	54
7	1·0057256	1·0077639	1·0101187	1·0127939	1·0157934	1·0191222	53
8	1·0057570	1·0078005	1·0101607	1·0128412	1·0158462	1·0191805	52
9	1·0057885	1·0078372	1·0102027	1·0128886	1·0158991	1·0192389	51
10	1·0058200	1·0078741	1·0102449	1·0129361	1·0159520	1·0192973	50
11	1·0058517	1·0079110	1·0102871	1·0129837	1·0160050	1·0193559	49
12	1·0058834	1·0079480	1·0103294	1·0130314	1·0160582	1·0194146	48
13	1·0050158	1·0079851	1·0103718	1·0130791	1·0161114	1·0194734	47
14	1·0050472	1·0080222	1·0104143	1·0131270	1·0161647	1·0195323	46
15	1·0059792	1·0080595	1·0104568	1·0131750	1·0162181	1·0195912	45
16	1·0000118	1·0080968	1·0104995	1·0132230	1·0162716	1·0196502	44
17	1·0000435	1·0081343	1·0105422	1·0132711	1·0163252	1·0197093	43
18	1·0060757	1·0081718	1·0105851	1·0133194	1·0163789	1·0197686	42
19	1·0061081	1·0082094	1·0106280	1·0133677	1·0164327	1·0198279	41
20	1·0061405	1·0082471	1·0106710	1·0134161	1·0164865	1·0198873	40
21	1·0061781	1·0082849	1·0107141	1·0134646	1·0165405	1·0199468	39
22	1·0062057	1·0083228	1·0107573	1·0135132	1·0165946	1·0200064	38
23	1·0062384	1·0083607	1·0108006	1·0135618	1·0166487	1·0200661	37
24	1·0062712	1·0083988	1·0108440	1·0136106	1·0167029	1·0201259	36
25	1·0063040	1·0084369	1·0108875	1·0136595	1·0167573	1·0201858	35
26	1·0063370	1·0084752	1·0109310	1·0137084	1·0168117	1·0202457	34
27	1·0063701	1·0085135	1·0109747	1·0137574	1·0168662	1·0203058	33
28	1·0064032	1·0085519	1·0110184	1·0138066	1·0169208	1·0203660	32
29	1·0064304	1·0085904	1·0110622	1·0138558	1·0169755	1·0204262	31
30	1·0064697	1·0086290	1·0111061	1·0139051	1·0170303	1·0204866	30
31	1·0065031	1·0086676	1·0111501	1·0139545	1·0170851	1·0205470	29
32	1·0065366	1·0087064	1·0111942	1·0140040	1·0171401	1·0206075	28
33	1·0065702	1·0087452	1·0112384	1·0140536	1·0171952	1·0206682	27
34	1·0066039	1·0087842	1·0112827	1·0141032	1·0172503	1·0207289	26
35	1·0066376	1·0088232	1·0113270	1·0141530	1·0173056	1·0207897	25
36	1·0066714	1·0088623	1·0113715	1·0142029	1·0173609	1·0208506	24
37	1·0067054	1·0089015	1·0114160	1·0142528	1·0174163	1·0209116	23
38	1·0067394	1·0089408	1·0114606	1·0143028	1·0174719	1·0209727	22
39	1·0067735	1·0089802	1·0115054	1·0143530	1·0175275	1·0210339	21
40	1·0068077	1·0090196	1·0115502	1·0144032	1·0175832	1·0210952	20
41	1·0068419	1·0090592	1·0115951	1·0144535	1·0176390	1·0211566	19
42	1·0068763	1·0090988	1·0116400	1·1145039	1·0176949	1·0212180	18
43	1·0069108	1·0091386	1·0116851	1·0145544	1·0177509	1·0212796	17
44	1·0069453	1·0091784	1·0117303	1·0146050	1·0178069	1·0213413	16
45	1·0069799	1·0092183	1·0117755	1·0146556	1·0178631	1·0214030	15
46	1·0070146	1·0092583	1·0118209	1·0147064	1·0179194	1·0214649	14
47	1·0070494	1·0092984	1·0118663	1·0147573	1·0179757	1·0215268	13
48	1·0070843	1·0093386	1·0119118	1·0148082	1·0180321	1·0215888	12
49	1·0071193	1·0093788	1·0119575	1·0148592	1·0180887	1·0216510	11
50	1·0071544	1·0094192	1·0120032	1·0149103	1·0181453	1·0217133	10
51	1·0071895	1·0094596	1·0120489	1·0149616	1·0182020	1·0217755	9
52	1·0072248	1·0095001	1·0120948	1·0150129	1·0182588	1·0218379	8
53	1·0072601	1·0095408	1·0121408	1·0150643	1·0183158	1·0219004	7
54	1·0072955	1·0095815	1·0121869	1·0151158	1·0183728	1·0219630	6
55	1·0073310	1·0096223	1·0122330	1·0151673	1·0184298	1·0220257	5
56	1·0073666	1·0096631	1·0122793	1·0152190	1·0184870	1·0220885	4
57	1·0074023	1·0097041	1·0123256	1·0152708	1·0185443	1·0221514	3
58	1·0074380	1·0097452	1·0123720	1·0153226	1·0186017	1·0222144	2
59	1·0074739	1·0097863	1·0124185	1·0153746	1·0186591	1·0222774	1
60	1·0075098	1·0098276	1·0124651	1·0154266	1·0187167	1·0223406	0
′	83°	82°	81°	80°	79°	78°	′

COSECANTS.

SECANTS.

′	12°	13°	14°	15°	16°	17°	′
0	1·0223406	1·0263041	1·0306136	1·0352762	1·0402994	1·0456918	60
1	1·0224039	1·0263731	1·0306884	1·0353569	1·0403863	1·0457848	59
2	1·0224672	1·0264421	1·0307633	1·0354378	1·0404732	1·0458780	58
3	1·0225307	1·0265113	1·0308383	1·0355187	1·0405602	1·0459712	57
4	1·0225942	1·0265806	1·0309134	1·0355998	1·0406473	1·0460646	56
5	1·0226578	1·0266499	1·0309886	1·0356809	1·0407346	1·0461581	55
6	1·0227216	1·0267194	1·0310639	1·0357621	1·0408219	1·0462516	54
7	1·0227854	1·0267889	1·0311393	1·0358435	1·0409094	1·0463453	53
8	1·0228493	1·0268586	1·0312147	1·0359249	1·0409969	1·0464391	52
9	1·0229133	1·0269283	1·0312903	1·0360065	1·0410845	1·0465330	51
10	1·0229774	1·0269982	1·0313660	1·0360881	1·0411723	1·0466270	50
11	1·0230416	1·0270681	1·0314418	1·0361699	1·0412601	1·0467211	49
12	1·0231059	1·0271381	1·0315177	1·0362517	1·0413481	1·0468153	48
13	1·0231703	1·0272082	1·0315936	1·0363337	1·0414362	1·0469096	47
14	1·0232348	1·0272785	1·0316697	1·0364157	1·0415243	1·0470040	46
15	1·0232994	1·0273488	1·0317459	1·0364979	1·0416126	1·0470986	45
16	1·0233641	1·0274192	1·0318222	1·0365801	1·0417009	1·0471932	44
17	1·0234288	1·0274897	1·0318985	1·0366625	1·0417894	1·0472879	43
18	1·0234937	1·0275603	1·0319750	1·0367449	1·0418780	1·0473828	42
19	1·0235587	1·0276310	1·0320516	1·0368275	1·0419667	1·0474777	41
20	1·0236237	1·0277018	1·0321282	1·0369101	1·0420554	1·0475728	40
21	1·0236889	1·0277727	1·0322050	1·0369929	1·0421443	1·0476679	39
22	1·0237541	1·0278437	1·0322818	1·0370757	1·0422333	1·0477632	38
23	1·0238195	1·0279148	1·0323588	1·0371587	1·0423224	1·0478586	37
24	1·0238849	1·0279860	1·0324359	1·0372417	1·0424116	1·0479540	36
25	1·0239504	1·0280573	1·0325130	1·0373249	1·0425009	1·0480496	35
26	1·0240161	1·0281287	1·0325903	1·0374082	1·0425903	1·0481453	34
27	1·0240818	1·0282002	1·0326676	1·0374915	1·0426798	1·0482411	33
28	1·0241476	1·0282717	1·0327451	1·0375750	1·0427694	1·0483370	32
29	1·0242135	1·0283434	1·0328227	1·0376585	1·0428591	1·0484330	31
30	1·0242795	1·0284152	1·0329003	1·0377422	1·0429489	1·0485291	30
31	1·0243456	1·0284871	1·0329781	1·0378260	1·0430388	1·0486253	29
32	1·0244118	1·0285590	1·0330559	1·0379098	1·0431289	1·0487217	28
33	1·0244781	1·0286311	1·0331339	1·0379938	1·0432190	1·0488181	27
34	1·0245445	1·0287033	1·0332119	1·0380779	1·0433092	1·0489146	26
35	1·0246110	1·0287755	1·0332901	1·0381621	1·0433995	1·0490113	25
36	1·0246776	1·0288479	1·0333683	1·0382463	1·0434900	1·0491080	24
37	1·0247443	1·0289203	1·0334467	1·0383307	1·0435805	1·0492049	23
38	1·0248110	1·0289929	1·0335251	1·0384152	1·0436712	1·0493019	22
39	1·0248779	1·0290655	1·0336037	1·0384998	1·0437619	1·0493989	21
40	1·0249448	1·0291383	1·0336823	1·0385844	1·0438528	1·0494961	20
41	1·0250119	1·0292111	1·0337611	1·0386692	1·0439437	1·0495934	19
42	1·0250790	1·0292840	1·0338399	1·0387541	1·0440348	1·0496908	18
43	1·0251463	1·0293571	1·0339188	1·0388391	1·0441259	1·0497883	17
44	1·0252136	1·0294302	1·0339979	1·0389242	1·0442172	1·0498859	16
45	1·0252811	1·0295034	1·0340770	1·0390094	1·0443086	1·0499836	15
46	1·0253486	1·0295768	1·0341562	1·0390947	1·0444001	1·0500815	14
47	1·0254163	1·0296502	1·0342356	1·0391800	1·0444917	1·0501794	13
48	1·0254839	1·0297237	1·0343151	1·0392655	1·0445833	1·0502774	12
49	1·0255518	1·0297973	1·0343946	1·0393511	1·0446751	1·0503756	11
50	1·0256197	1·0298711	1·0344743	1·0394368	1·0447670	1·0504738	10
51	1·0256877	1·0299449	1·0345540	1·0395226	1·0448590	1·0505722	9
52	1·0257558	1·0300188	1·0346338	1·0396085	1·0449511	1·0506706	8
53	1·0258240	1·0300928	1·0347138	1·0396945	1·0450433	1·0507692	7
54	1·0258923	1·0301669	1·0347938	1·0397806	1·0451357	1·0508679	6
55	1·0259607	1·0302411	1·0348740	1·0398669	1·0452281	1·0509667	5
56	1·0260292	1·0303154	1·0349542	1·0399532	1·0453206	1·0510656	4
57	1·0260978	1·0303898	1·0350346	1·0400396	1·0454132	1·0511646	3
58	1·0261665	1·0304643	1·0351150	1·0401261	1·0455060	1·0512637	2
59	1·0262352	1·0305389	1·0351955	1·0402127	1·0455988	1·0513629	1
60	1·0263041	1·0306136	1·0352762	1·0402994	1·0456918	1·0514622	0
′	77°	76°	75°	74°	73°	72°	′

COSECANTS.

SECANTS.

′	18°	19°	20°	21°	22°	23°	′
0	1·0514622	1·0576207	1·0641778	1·0711450	1·0785347	1·0863604	60
1	1·0515617	1·0577267	1·0642905	1·0712647	1·0786616	1·0864946	59
2	1·0516612	1·0578328	1·0644033	1·0713844	1·0787885	1·0866289	58
3	1·0517608	1·0579390	1·0645163	1·0715043	1·0789156	1·0867634	57
4	1·0518606	1·0580453	1·0646294	1·0716244	1·0790427	1·0868979	56
5	1·0519605	1·0581517	1·0647425	1·0717445	1·0791700	1·0870326	55
6	1·0520604	1·0582583	1·0648558	1·0718647	1·0792975	1·0871675	54
7	1·0521605	1·0583649	1·0649693	1·0719851	1·0794250	1·0873024	53
8	1·0522607	1·0584717	1·0650828	1·0721056	1·0795527	1·0874375	52
9	1·0523610	1·0585786	1·0651964	1·0722262	1·0796805	1·0875727	51
10	1·0524614	1·0586855	1·0653102	1·0723469	1·0798084	1·0877080	50
11	1·0525619	1·0587926	1·0654240	1·0724678	1·0799364	1·0878435	49
12	1·0526625	1·0588999	1·0655380	1·0725887	1·0800646	1·0879791	48
13	1·0527633	1·0590072	1·0656521	1·0727098	1·0801928	1·0881148	47
14	1·0528641	1·0591146	1·0657663	1·0728310	1·0803212	1·0882506	46
15	1·0529651	1·0592221	1·0658807	1·0729523	1·0804497	1·0883866	45
16	1·0530661	1·0593298	1·0659951	1·0730737	1·0805784	1·0885226	44
17	1·0531673	1·0594376	1·0661097	1·0731953	1·0807071	1·0886589	43
18	1·0532686	1·0595454	1·0662243	1·0733170	1·0808360	1·0887952	42
19	1·0533699	1·0596534	1·0663391	1·0734388	1·0809650	1·0889317	41
20	1·0534714	1·0597615	1·0664540	1·0735607	1·0810942	1·0890682	40
21	1·0535730	1·0598697	1·0665690	1·0736827	1·0812234	1·0892050	39
22	1·0536747	1·0599781	1·0666842	1·0738048	1·0813528	1·0893418	38
23	1·0537765	1·0600865	1·0667994	1·0739271	1·0814823	1·0894788	37
24	1·0538785	1·0601951	1·0669148	1·0740495	1·0816119	1·0896159	36
25	1·0539805	1·0603037	1·0670302	1·0741720	1·0817417	1·0897531	35
26	1·0540826	1·0604125	1·0671458	1·0742946	1·0818715	1·0898904	34
27	1·0541849	1·0605214	1·0672615	1·0744173	1·0820015	1·0900279	33
28	1·0542873	1·0606304	1·0673774	1·0745402	1·0821316	1·0901655	32
29	1·0543897	1·0607395	1·0674933	1·0746631	1·0822618	1·0903032	31
30	1·0544923	1·0608487	1·0676094	1·0747862	1·0823923	1·0904411	30
31	1·0545950	1·0609580	1·0677255	1·0749095	1·0825227	1·0905791	29
32	1·0546978	1·0610675	1·0678418	1·0750328	1·0826533	1·0907172	28
33	1·0548007	1·0611770	1·0679582	1·0751562	1·0827840	1·0908554	27
34	1·0549037	1·0612867	1·0680747	1·0752798	1·0829149	1·0909938	26
35	1·0550068	1·0613965	1·0681914	1·0754035	1·0830458	1·0911323	25
36	1·0551101	1·0615064	1·0683081	1·0755273	1·0831769	1·0912709	24
37	1·0552134	1·0616164	1·0684250	1·0756512	1·0833081	1·0914097	23
38	1·0553169	1·0617265	1·0685420	1·0757753	1·0834395	1·0915485	22
39	1·0554204	1·0618367	1·0686591	1·0758995	1·0835709	1·0916876	21
40	1·0555241	1·0619471	1·0687763	1·0760237	1·0837025	1·0918267	20
41	1·0556279	1·0620575	1·0688936	1·0761481	1·0838342	1·0919659	19
42	1·0557318	1·0621681	1·0690110	1·0762727	1·0839661	1·0921053	18
43	1·0558358	1·0622788	1·0691286	1·0763973	1·0840980	1·0922448	17
44	1·0559399	1·0623896	1·0692463	1·0765221	1·0842301	1·0923845	16
45	1·0560441	1·0625005	1·0693641	1·0766470	1·0843623	1·0925243	15
46	1·0561485	1·0626115	1·0694820	1·0767720	1·0844947	1·0926642	14
47	1·0562529	1·0627227	1·0696000	1·0768971	1·0846271	1·0928042	13
48	1·0563575	1·0628339	1·0697182	1·0770224	1·0847597	1·0929444	12
49	1·0564621	1·0629453	1·0698364	1·0771477	1·0848924	1·0930846	11
50	1·0565669	1·0630568	1·0699548	1·0772732	1·0850252	1·0932251	10
51	1·0566718	1·0631684	1·0700733	1·0773988	1·0851582	1·0933656	9
52	1·0567768	1·0632801	1·0701919	1·0775246	1·0852913	1·0935063	8
53	1·0568819	1·0633919	1·0703105	1·0776504	1·0854245	1·0936471	7
54	1·0569871	1·0635038	1·0704295	1·0777764	1·0855578	1·0937880	6
55	1·0570924	1·0636158	1·0705484	1·0779025	1·0856912	1·0939291	5
56	1·0571978	1·0637280	1·0706675	1·0780287	1·0858248	1·0940702	4
57	1·0573034	1·0638403	1·0707867	1·0781550	1·0859585	1·0942116	3
58	1·0574090	1·0639527	1·0709060	1·0782815	1·0860924	1·0943530	2
59	1·0575148	1·0640652	1·0710254	1·0784080	1·0862263	1·0944946	1
60	1·0576207	1·0641778	1·0711450	1·0785347	1·0863604	1·0946363	0
′	71°	70°	69°	68°	67°	66°	′

COSECANTS.

Secants.

′	24°	25°	26°	27°	28°	29°	′
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8
53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6
55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5
56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
′	65°	64°	63°	62°	61°	60°	′

SECANTS.

′	30°	31°	32°	33°	34°	35°	′
0	1·1547005	1·1666334	1·1791784	1·1923633	1·2062179	1·2207746	60
1	1·1548945	1·1668374	1·1793928	1·1925886	1·2064547	1·2210233	59
2	1·1550887	1·1670416	1·1796074	1·1928142	1·2066917	1·2212723	58
3	1·1552830	1·1672459	1·1798222	1·1930399	1·2069288	1·2215215	57
4	1·1554775	1·1674504	1·1800372	1·1932658	1·2071662	1·2217708	56
5	1·1556722	1·1676551	1·1802523	1·1934918	1·2074037	1·2220204	55
6	1·1558670	1·1678599	1·1804676	1·1937181	1·2076415	1·2222702	54
7	1·1560620	1·1680649	1·1806831	1·1939446	1·2078794	1·2225202	53
8	1·1562572	1·1682701	1·1808988	1·1941712	1·2081175	1·2227703	52
9	1·1564525	1·1684755	1·1811146	1·1943980	1·2083559	1·2230207	51
10	1·1566480	1·1686810	1·1813307	1·1946251	1·2085944	1·2232713	50
11	1·1568436	1·1688867	1·1815469	1·1948523	1·2088331	1·2235222	49
12	1·1570394	1·1690926	1·1817633	1·1950796	1·2090720	1·2237732	48
13	1·1572354	1·1692986	1·1819798	1·1953072	1·2093112	1·2240244	47
14	1·1574315	1·1695048	1·1821966	1·1955350	1·2095505	1·2242758	46
15	1·1576278	1·1697112	1·1824135	1·1957629	1·2097900	1·2245274	45
16	1·1578243	1·1699178	1·1826306	1·1959911	1·2100297	1·2247793	44
17	1·1580209	1·1701245	1·1828479	1·1962194	1·2102696	1·2250313	43
18	1·1582177	1·1703314	1·1830654	1·1964479	1·2105097	1·2252836	42
19	1·1584146	1·1705385	1·1832830	1·1966767	1·2107500	1·2255361	41
20	1·1586118	1·1707457	1·1835008	1·1969056	1·2109905	1·2257887	40
21	1·1588091	1·1709531	1·1837188	1·1971346	1·2112312	1·2260416	39
22	1·1590065	1·1711607	1·1839370	1·1973639	1·2114721	1·2262947	38
23	1·1592041	1·1713685	1·1841554	1·1975934	1·2117132	1·2265480	37
24	1·1594019	1·1715764	1·1843739	1·1978230	1·2119545	1·2268015	36
25	1·1595999	1·1717845	1·1845927	1·1980529	1·2121960	1·2270552	35
26	1·1597980	1·1719928	1·1848116	1·1982829	1·2124377	1·2273091	34
27	1·1599963	1·1722013	1·1850307	1·1985131	1·2126795	1·2275633	33
28	1·1601947	1·1724099	1·1852500	1·1987435	1·2129216	1·2278176	32
29	1·1603933	1·1726187	1·1854694	1·1989741	1·2131639	1·2280722	31
30	1·1605921	1·1728277	1·1856890	1·1992049	1·2134064	1·2283269	30
31	1·1607911	1·1730368	1·1859089	1·1994359	1·2136491	1·2285819	29
32	1·1609902	1·1732462	1·1861289	1·1996671	1·2138920	1·2288371	28
33	1·1611894	1·1734557	1·1863490	1·1998985	1·2141351	1·2290924	27
34	1·1613889	1·1736653	1·1865694	1·2001300	1·2143784	1·2293480	26
35	1·1615885	1·1738752	1·1867900	1·2003618	1·2146218	1·2296039	25
36	1·1617883	1·1740852	1·1870107	1·2005937	1·2148655	1·2298599	24
37	1·1619882	1·1742954	1·1872316	1·2008258	1·2151094	1·2301161	23
38	1·1621883	1·1745058	1·1874527	1·2010582	1·2153535	1·2303725	22
39	1·1623886	1·1747163	1·1876740	1·2012907	1·2155978	1·2306292	21
40	1·1625891	1·1749270	1·1878954	1·2015234	1·2158423	1·2308861	20
41	1·1627897	1·1751379	1·1881171	1·2017563	1·2160870	1·2311432	19
42	1·1629905	1·1753490	1·1883389	1·2019894	1·2163319	1·2314004	18
43	1·1631914	1·1755603	1·1885609	1·2022226	1·2165770	1·2316579	17
44	1·1633925	1·1757717	1·1887831	1·2024561	1·2168223	1·2319156	16
45	1·1635938	1·1759833	1·1890055	1·2026898	1·2170678	1·2321736	15
46	1·1637953	1·1761951	1·1892280	1·2029236	1·2173135	1·2324317	14
47	1·1639969	1·1764070	1·1894508	1·2031577	1·2175594	1·2326900	13
48	1·1641987	1·1766191	1·1896737	1·2033919	1·2178055	1·2329486	12
49	1·1644007	1·1768314	1·1898968	1·2036264	1·2180518	1·2332074	11
50	1·1646028	1·1770439	1·1901201	1·2038610	1·2182983	1·2334664	10
51	1·1648051	1·1772566	1·1903436	1·2040958	1·2185450	1·2337256	9
52	1·1650076	1·1774694	1·1905673	1·2043308	1·2187919	1·2339850	8
53	1·1652102	1·1776824	1·1907911	1·2045660	1·2190390	1·2342446	7
54	1·1654130	1·1778956	1·1910152	1·2048014	1·2192864	1·2345044	6
55	1·1656160	1·1781089	1·1912394	1·2050370	1·2195339	1·2347645	5
56	1·1658191	1·1783225	1·1914638	1·2052728	1·2197816	1·2350248	4
57	1·1660224	1·1785362	1·1916884	1·2055088	1·2200296	1·2352852	3
58	1·1662259	1·1787501	1·1919132	1·2057450	1·2202777	1·2355459	2
59	1·1664296	1·1789642	1·1921381	1·2059814	1·2205260	1·2358069	1
60	1·1666334	1·1791784	1·1923633	1·2062179	1·2207746	1·2360680	0
′	59°	58°	57°	56°	55°	54°	′

COSECANTS.

SECANTS.

′	36°	37°	38°	39°	40°	41°	′
0	1·2360680	1·2521357	1·2690182	1·2867596	1·3054073	1·3250130	60
1	1·2363293	1·2524102	1·2693067	1·2870628	1·3057261	1·3253482	59
2	1·2365909	1·2526850	1·2695955	1·2873663	1·3060451	1·3256837	58
3	1·2368526	1·2529601	1·2698845	1·2876700	1·3063644	1·3260191	57
4	1·2371146	1·2532353	1·2701737	1·2879740	1·3066839	1·3263554	56
5	1·2373768	1·2535108	1·2704632	1·2882782	1·3070038	1·3266918	55
6	1·2376393	1·2537865	1·2707529	1·2885827	1·3073239	1·3270284	54
7	1·2379019	1·2510625	1·2710429	1·2888875	1·3076442	1·3273652	53
8	1·2381647	1·2543387	1·2713331	1·2891925	1·3079649	1·3277024	52
9	1·2384278	1·2546151	1·2716235	1·2894977	1·3082858	1·3280399	51
10	1·2386911	1·2548917	1·2719142	1·2898032	1·3086069	1·3283776	50
11	1·2389546	1·2551685	1·2722052	1·2901090	1·3089284	1·3287156	49
12	1·2392183	1·2554456	1·2724963	1·2904150	1·3092501	1·3290539	48
13	1·2394823	1·2557229	1·2727877	1·2907213	1·3095720	1·3293925	47
14	1·2397464	1·2560005	1·2730794	1·2910278	1·3098943	1·3297314	46
15	1·2400108	1·2562783	1·2733713	1·2913346	1·3102168	1·3300706	45
16	1·2402754	1·2565563	1·2736634	1·2916416	1·3105396	1·3304100	44
17	1·2405402	1·2568345	1·2739557	1·2919489	1·3108626	1·3307497	43
18	1·2408052	1·2571129	1·2712484	1·2922564	1·3111860	1·3310897	42
19	1·2410704	1·2573916	1·2745412	1·2925642	1·3115095	1·3314301	41
20	1·2413359	1·2576705	1·2748343	1·2928723	1·3118334	1·3317707	40
21	1·2416016	1·2579497	1·2751276	1·2931806	1·3121575	1·3321115	39
22	1·2418675	1·2582291	1·2751212	1·2934892	1·3124820	1·3324527	38
23	1·2421336	1·2585087	1·2757151	1·2937980	1·3128066	1·3327942	37
24	1·2423999	1·2587885	1·2760091	1·2941071	1·3131316	1·3331359	36
25	1·2426665	1·2590686	1·2763034	1·2944164	1·3134568	1·3334779	35
26	1·2429333	1·2593489	1·2765980	1·2947260	1·3137823	1·3338203	34
27	1·2432003	1·2596294	1·2768928	1·2950359	1·3141081	1·3341629	33
28	1·2434675	1·2599102	1·2771878	1·2953460	1·3144341	1·3345058	32
29	1·2437349	1·2601912	1·2774831	1·2956564	1·3147604	1·3348489	31
30	1·2440026	1·2604724	1·2777787	1·2959670	1·3150870	1·3351924	30
31	1·2442704	1·2607539	1·2780744	1·2962779	1·3154139	1·3355362	29
32	1·2415385	1·2610356	1·2783705	1·2965890	1·3157410	1·3358802	28
33	1·2448069	1·2613175	1·2786667	1·2969004	1·3160684	1·3362246	27
34	1·2450754	1·2615997	1·2789632	1·2972121	1·3163961	1·3365692	26
35	1·2453442	1·2618820	1·2792600	1·2975240	1·3167240	1·3369141	25
36	1·2456131	1·2621647	1·2795570	1·2978362	1·3170523	1·3372594	24
37	1·2458823	1·2624475	1·2798543	1·2981487	1·3173808	1·3376049	23
38	1·2461518	1·2627306	1·2801518	1·2984614	1·3177096	1·3379507	22
39	1·2464214	1·2630140	1·2804495	1·2987743	1·3180386	1·6382968	21
40	1·2466913	1·2632975	1·2807475	1·2990876	1·3183680	1·3386432	20
41	1·2469614	1·2635813	1·2810457	1·2991011	1·3186976	1·3389898	19
42	1·2472317	1·2638653	1·2813442	1·2997148	1·3190274	1·3393368	18
43	1·2475022	1·2641496	1·2816430	1·3000288	1·3193576	1·3396841	17
44	1·2477730	1·2644341	1·2819419	1·3003431	1·3196881	1·3400316	16
45	1·2480440	1·2647188	1·2822412	1·3006576	1·3200188	1·3403795	15
46	1·2483152	1·2650038	1·2825407	1·3009724	1·3203498	1·3407276	14
47	1·2485866	1·2652890	1·2828404	1·3012875	1·3206810	1·3410761	13
48	1·2488583	1·2655745	1·2831404	1·3016028	1·3210126	1·3414248	12
49	1·2491302	1·2658601	1·2834406	1·3019184	1·3213444	1·3417738	11
50	1·2494023	1·2661460	1·2837411	1·3022343	1·3216765	1·3421232	10
51	1·2496746	1·2664322	1·2840418	1·3025504	1·3220089	1·3424728	9
52	1·2499471	1·2667186	1·2843423	1·3028667	1·3223416	1·3428227	8
53	1·2502199	1·2670052	1·2846440	1·3031834	1·3226745	1·3431729	7
54	1·2504929	1·2672921	1·2849455	1·3035003	1·3230078	1·3435234	6
55	1·2507661	1·2675792	1·2852472	1·3038175	1·3233413	1·3438742	5
56	1·2510396	1·2678665	1·2855492	1·3041349	1·3236750	1·3442253	4
57	1·2513133	1·2681541	1·2858514	1·3044526	1·3240091	1·3445767	3
58	1·2515872	1·2684419	1·2861539	1·3047706	1·3243435	1·3449284	2
59	1·2518613	1·2687299	1·2864566	1·3050888	1·3246781	1·3452804	1
60	1·2521357	1·2690182	1·2867596	1·3054073	1·3250130	1·3456327	0
′	53°	52°	51°	50°	49°	48°	′

COSECANTS.

SECANTS.

′	42°	43°	44°	45°	46°	47°	′
0	1·3456327	1·3673275	1·3901636	1·4142136	1·4395565	1·4662792	60
1	1·3459853	1·3676985	1·3905543	1·4146251	1·4399904	1·4667368	59
2	1·3463383	1·3680699	1·3909453	1·4150370	1·4404246	1·4671948	58
3	1·3466914	1·3684416	1·3913366	1·4154493	1·4408592	1·4676532	57
4	1·3470449	1·3688136	1·3917283	1·4158619	1·4412941	1·4681120	56
5	1·3473987	1·3691859	1·3921203	1·4162749	1·4417295	1·4685713	55
6	1·3477528	1·3695586	1·3925127	1·4166883	1·4421652	1·4690309	54
7	1·3481072	1·3699315	1·3929054	1·4171020	1·4426013	1·4694910	53
8	1·3484619	1·3703048	1·3932985	1·4175161	1·4430379	1·4699514	52
9	1·3488168	1·3706784	1·3936918	1·4179306	1·4434748	1·4704123	51
10	1·3491721	1·3710523	1·3940856	1·4183454	1·4439120	1·4708736	50
11	1·3495277	1·3714266	1·3914796	1·4187605	1·4443497	1·4713354	49
12	1·3498836	1·3718011	1·3948740	1·4191761	1·4447878	1·4717975	48
13	1·3502398	1·3721760	1·3952688	1·4195920	1·4452263	1·4722600	47
14	1·3505963	1·3725512	1·3956639	1·4200083	1·4456651	1·4727230	46
15	1·3509531	1·3729268	1·3960593	1·4204248	1·4461043	1·4731864	45
16	1·3513102	1·3733026	1·3964551	1·4208418	1·4465439	1·4736502	44
17	1·3516677	1·3736788	1·3968512	1·4212592	1·4469839	1·4741144	43
18	1·3520254	1·3740553	1·3972477	1·4216769	1·4474243	1·4745790	42
19	1·3523834	1·3744321	1·3976445	1·4220950	1·4478651	1·4750440	41
20	1·3527417	1·3748092	1·3980416	1·4225134	1·4483063	1·4755095	40
21	1·3531003	1·3751867	1·3984391	1·4229323	1·4487478	1·4759754	39
22	1·3534593	1·3755645	1·3988369	1·4233514	1·4491898	1·4764417	38
23	1·3538185	1·3759426	1·3992351	1·4237710	1·4496322	1·4769084	37
24	1·3541780	1·3763210	1·3996336	1·4241909	1·4500749	1·4773755	36
25	1·3545379	1·3766998	1·4000325	1·4246112	1·4505181	1·4778431	35
26	1·3548980	1·3770789	1·4004317	1·4250319	1·4509616	1·4788111	34
27	1·3552585	1·3774583	1·4008313	1·4254529	1·4514055	1·4787795	33
28	1·3556193	1·3778380	1·4012312	1·4258743	1·4518498	1·4792483	32
29	1·3559803	1·3782181	1·4016315	1·4262961	1·4522946	1·4797176	31
30	1·3563417	1·3785985	1·4020321	1·4267182	1·4527397	1·4801872	30
31	1·3567034	1·3789792	1·4024330	1·4271407	1·4531852	1·4806578	29
32	1·3570654	1·3793602	1·4028343	1·4275636	1·4536311	1·4811278	28
33	1·3574277	1·3797416	1·4032360	1·4279868	1·4540774	1·4815988	27
34	1·3577903	1·3801233	1·4036380	1·4284105	1·4545241	1·4820702	26
35	1·3581532	1·3805053	1·4040403	1·4288345	1·4549712	1·4825420	25
36	1·3585164	1·3808877	1·4044430	1·4292588	1·4554187	1·4830142	24
37	1·3588800	1·3812704	1·4048461	1·4296836	1·4558666	1·4834868	23
38	1·3592438	1·3816534	1·4052494	1·4301087	1·4563149	1·4839599	22
39	1·3596080	1·3820367	1·4056532	1·4305342	1·4567636	1·4844334	21
40	1·3599725	1·3824204	1·4060573	1·4309600	1·4572127	1·4849073	20
41	1·3603372	1·3828044	1·4064617	1·4313863	1·4576621	1·4853817	19
42	1·3607023	1·3831887	1·4068665	1·4318129	1·4581120	1·4858565	18
43	1·3610677	1·3835734	1·4072717	1·4322399	1·4585623	1·4863317	17
44	1·3614334	1·3839584	1·4076772	1·4326672	1·4590130	1·4868073	16
45	1·3617995	1·3843437	1·4080831	1·4330950	1·4594641	1·4872834	15
46	1·3621658	1·3847294	1·4084893	1·4335231	1·4599156	1·4877599	14
47	1·3625324	1·3851153	1·4088958	1·4339516	1·4603675	1·4882369	13
48	1·3628994	1·3855017	1·4093028	1·4343805	1·4608198	1·4887142	12
49	1·3632667	1·3858883	1·4097100	1·4348097	1·4612726	1·4891920	11
50	1·3636343	1·3862753	1·4101177	1·4352393	1·4617257	1·4896703	10
51	1·3640022	1·3866626	1·4105257	1·4356693	1·4621792	1·4901489	9
52	1·3643704	1·3870503	1·4109340	1·4360997	1·4626331	1·4906280	8
53	1·3647389	1·3874383	1·4113427	1·4365305	1·4630875	1·4911076	7
54	1·3651078	1·3878266	1·4117517	1·4369616	1·4635422	1·4915876	6
55	1·3654770	1·3882153	1·4121612	1·4373932	1·4639973	1·4920680	5
56	1·3658464	1·3886043	1·4125709	1·4378251	1·4644529	1·4925488	4
57	1·3662162	1·3889936	1·4129810	1·4382574	1·4649089	1·4930301	3
58	1·3665863	1·3893832	1·4133915	1·4386900	1·4653652	1·4935118	2
59	1·3669567	1·3897783	1·4138024	1·4391231	1·4658220	1·4939940	1
60	1·3673275	1·3901686	1·4142136	1·4395565	1·4662792	1·4944765	0
′	47°	46°	45°	44°	43°	42°	′

COSECANTS.

SECANTS.

′	48°	49°	50°	51°	52°	53°	′
0	1·4944765	1·5242531	1·5557238	1·5890157	1·6242692	1·6616401	60
1	1·4949596	1·5247634	1·5562634	1·5895868	1·6248743	1·6622819	59
2	1·4954431	1·5252741	1·5568035	1·5901584	1·6254799	1·6629243	58
3	1·4959270	1·5257854	1·5573441	1·5907306	1·6260861	1·6635673	57
4	1·4964113	1·5262971	1·5578852	1·5913033	1·6266929	1·6642110	56
5	1·4968961	1·5268093	1·5584268	1·5918766	1·6273003	1·6648553	55
6	1·4973812	1·5273219	1·5589689	1·5924504	1·6279083	1·6655002	54
7	1·4978670	1·5278351	1·5595115	1·5930247	1·6285169	1·6661458	53
8	1·4983531	1·5283487	1·5600546	1·5935996	1·6291261	1·6667920	52
9	1·4988397	1·5288627	1·5605982	1·5941751	1·6297359	1·6674389	51
10	1·4993267	1·5293773	1·5611424	1·5947511	1·6303462	1·6680864	50
11	1·4998141	1·5298923	1·5616871	1·5953276	1·6309572	1·6687345	49
12	1·5003020	1·5304078	1·5622322	1·5959048	1·6315688	1·6693833	48
13	1·5007903	1·5309238	1·5627779	1·5964824	1·6321809	1·6700328	47
14	1·5012791	1·5314403	1·5633241	1·5970606	1·6327937	1·6706828	46
15	1·5017683	1·5319572	1·5638708	1·5976394	1·6334070	1·6713336	45
16	1·5022580	1·5324746	1·5644181	1·5982187	1·6340210	1·6719850	44
17	1·5027481	1·5329925	1·5649658	1·5987986	1·6346355	1·6726370	43
18	1·5032387	1·5335109	1·5655141	1·5993790	1·6352507	1·6732897	42
19	1·5037297	1·5340297	1·5660628	1·5999600	1·6358664	1·6739430	41
20	1·5042211	1·5345491	1·5666121	1·6005416	1·6364828	1·6745970	40
21	1·5047131	1·5350689	1·5671619	1·6011237	1·6370997	1·6752517	39
22	1·5052054	1·5355892	1·5677123	1·6017064	1·6377173	1·6759070	38
23	1·5056982	1·5361100	1·5682631	1·6022896	1·6383355	1·6765629	37
24	1·5061915	1·5366313	1·5688145	1·6028734	1·6389542	1·6772195	36
25	1·5066852	1·5371530	1·5693664	1·6034577	1·6395736	1·6778768	35
26	1·5071793	1·5376753	1·5699188	1·6040426	1·6401936	1·6785347	34
27	1·5076739	1·5381980	1·5704717	1·6046281	1·6408142	1·6791933	33
28	1·5081690	1·5387212	1·5710252	1·6052142	1·6414354	1·6798525	32
29	1·5086645	1·5392449	1·5715792	1·6058008	1·6420572	1·6805124	31
30	1·5091605	1·5397690	1·5721337	1·6063879	1·6426796	1·6811730	30
31	1·5096569	1·5402937	1·5726887	1·6069757	1·6433027	1·6818342	29
32	1·5101538	1·5408189	1·5732443	1·6075640	1·6439263	1·6824961	28
33	1·5106511	1·5413445	1·5738004	1·6081528	1·6445506	1·6831586	27
34	1·5111489	1·5418706	1·5743570	1·6087423	1·6451754	1·6838219	26
35	1·5116472	1·5423973	1·5749141	1·6093323	1·6458009	1·6844857	25
36	1·5121459	1·5429244	1·5754718	1·6099228	1·6464270	1·6851503	24
37	1·5126450	1·5434520	1·5760300	1·6105140	1·6470537	1·6858155	23
38	1·5131446	1·5439801	1·5765887	1·6111057	1·6476811	1·6864814	22
39	1·5136447	1·5445087	1·5771479	1·6116980	1·6483090	1·6871479	21
40	1·5141452	1·5450378	1·5777077	1·6122908	1·6489376	1·6878151	20
41	1·5146462	1·5455673	1·5782680	1·6128843	1·6495668	1·6884830	19
42	1·5151477	1·5460974	1·5788289	1·6134783	1·6501966	1·6891516	18
43	1·5156496	1·5466280	1·5793902	1·6140728	1·6508270	1·6898208	17
44	1·5161520	1·5471590	1·5799521	1·6146680	1·6514581	1·6904907	16
45	1·5166548	1·5476906	1·5805146	1·6152637	1·6520898	1·6911613	15
46	1·5171581	1·5482226	1·5810776	1·6158600	1·6527221	1·6918326	14
47	1·5176619	1·5487552	1·5816411	1·6164569	1·6533550	1·6925045	13
48	1·5181661	1·5492882	1·5822051	1·6170544	1·6539885	1·6931771	12
49	1·5186708	1·5498218	1·5827697	1·6176524	1·6546227	1·6938504	11
50	1·5191759	1·5503558	1·5833348	1·6182510	1·6552575	1·6945244	10
51	1·5196815	1·5508904	1·5839005	1·6188502	1·6558929	1·6951990	9
52	1·5201876	1·5514254	1·5844667	1·6194500	1·6565290	1·6958744	8
53	1·5206942	1·5519610	1·5850334	1·6200504	1·6571657	1·6965504	7
54	1·5212012	1·5524970	1·5856007	1·6206513	1·6578030	1·6972271	6
55	1·5217087	1·5530335	1·5861685	1·6212528	1·6584409	1·6979044	5
56	1·5222166	1·5535706	1·5867369	1·6218549	1·6590795	1·6985825	4
57	1·5227250	1·5541081	1·5873058	1·6224576	1·6597187	1·6992612	3
58	1·5232339	1·5546462	1·5878752	1·6230609	1·6603586	1·6999407	2
59	1·5237433	1·5551848	1·5884452	1·6236648	1·6609990	1·7006208	1
60	1·5242531	1·5557238	1·5890157	1·6242692	1·6616401	1·7013016	0
′	41°	40°	39°	38°	37°	36°	′

COSECANTS.

SECANTS.

′	54°	55°	56°	57°	58°	59°	′
0	1·7013016	1·7434468	1·7882916	1·8360785	1·8870799	1·9416040	60
1	1·7019831	1·7441715	1·7890633	1·8369013	1·8879589	1·9425445	59
2	1·7026653	1·7448969	1·7898357	1·8377251	1·8888388	1·9434861	58
3	1·7033482	1·7456230	1·7906090	1·8385498	1·8897197	1·9444288	57
4	1·7040318	1·7463499	1·7913831	1·8393753	1·8906016	1·9453725	56
5	1·7047160	1·7470776	1·7921580	1·8402018	1·8914845	1·9463173	55
6	1·7054010	1·7478060	1·7929337	1·8410292	1·8923684	1·9472632	54
7	1·7060867	1·7485352	1·7937102	1·8418574	1·8932532	1·9482102	53
8	1·7067730	1·7492651	1·7944876	1·8426866	1·8941391	1·9491583	52
9	1·7074601	1·7499958	1·7952658	1·8435166	1·8950259	1·9501075	51
10	1·7081478	1·7507273	1·7960449	1·8443476	1·8959138	1·9510577	50
11	1·7088363	1·7514595	1·7968247	1·8451795	1·8968026	1·9520091	49
12	1·7095254	1·7521924	1·7976054	1·8460123	1·8976924	1·9529615	48
13	1·7102152	1·7529262	1·7983869	1·8468460	1·8985832	1·9539150	47
14	1·7109058	1·7536607	1·7991693	1·8476806	1·8994750	1·9548697	46
15	1·7115970	1·7543959	1·7999524	1·8485161	1·9003678	1·9558254	45
16	1·7122890	1·7551320	1·8007365	1·8493525	1·9012616	1·9567822	44
17	1·7129817	1·7558687	1·8015213	1·8501898	1·9021564	1·9577402	43
18	1·7136750	1·7566063	1·8023070	1·8510281	1·9030522	1·9586992	42
19	1·7143691	1·7573446	1·8030935	1·8518672	1·9039491	1·9596593	41
20	1·7150639	1·7580837	1·8038809	1·8527073	1·9048469	1·9606206	40
21	1·7157594	1·7588236	1·8046691	1·8535483	1·9057457	1·9615829	39
22	1·7164556	1·7595642	1·8054582	1·8543903	1·9066456	1·9625464	38
23	1·7171525	1·7603057	1·8062481	1·8552331	1·9075464	1·9635110	37
24	1·7178501	1·7610478	1·8070388	1·8560769	1·9084483	1·9644767	36
25	1·7185484	1·7617908	1·8078304	1·8569216	1·9093512	1·9654435	35
26	1·7192475	1·7625345	1·8086228	1·8577672	1·9102551	1·9664114	34
27	1·7199472	1·7632791	1·8094161	1·8586138	1·9111600	1·9673805	33
28	1·7206477	1·7640244	1·8102102	1·8594612	1·9120659	1·9683507	32
29	1·7213489	1·7647704	1·8110052	1·8603097	1·9129729	1·9693220	31
30	1·7220508	1·7655173	1·8118010	1·8611590	1·9138809	1·9702944	30
31	1·7227534	1·7662649	1·8125977	1·8620093	1·9147899	1·9712680	29
32	1·7234568	1·7670133	1·8133953	1·8628605	1·9156999	1·9722427	28
33	1·7241609	1·7677625	1·8141937	1·8637126	1·9166110	1·9732185	27
34	1·7248657	1·7685125	1·8149929	1·8645657	1·9175230	1·9741954	26
35	1·7255712	1·7692633	1·8157930	1·8654197	1·9184362	1·9751735	25
36	1·7262774	1·7700149	1·8165940	1·8662747	1·9193503	1·9761527	24
37	1·7269844	1·7707672	1·8173958	1·8671306	1·9202655	1·9771331	23
38	1·7276921	1·7715204	1·8181985	1·8679875	1·9211817	1·9781146	22
39	1·7284005	1·7722743	1·8190021	1·8688453	1·9220990	1·9790972	21
40	1·7291096	1·7730290	1·8198065	1·8697040	1·9230173	1·9800810	20
41	1·7298195	1·7737845	1·8206118	1·8705637	1·9239366	1·9810659	19
42	1·7305301	1·7745409	1·8214179	1·8714244	1·9248570	1·9820520	18
43	1·7312414	1·7752980	1·8222249	1·8722859	1·9257784	1·9830393	17
44	1·7319535	1·7760559	1·8230328	1·8731485	1·9267009	1·9840276	16
45	1·7326663	1·7768146	1·8238416	1·8740120	1·9276244	1·9850172	15
46	1·7333798	1·7775741	1·8246512	1·8748764	1·9285490	1·9860080	14
47	1·7340941	1·7783344	1·8254617	1·8757419	1·9294746	1·9869997	13
48	1·7348091	1·7790955	1·8262731	1·8766082	1·9304013	1·9879927	12
49	1·7355248	1·7798574	1·8270854	1·8774755	1·9313290	1·9889869	11
50	1·7362413	1·7806201	1·8278985	1·8783438	1·9322578	1·9899822	10
51	1·7369585	1·7813836	1·8287125	1·8792131	1·9331876	1·9909787	9
52	1·7376764	1·7821479	1·8295274	1·8800833	1·9341185	1·9919764	8
53	1·7383951	1·7829131	1·8303432	1·8809545	1·9350505	1·9929752	7
54	1·7391145	1·7836790	1·8311599	1·8818266	1·9359835	1·9939753	6
55	1·7398347	1·7844457	1·8319774	1·8826998	1·9369176	1·9949764	5
56	1·7405556	1·7852133	1·8327959	1·8835738	1·9378527	1·9959788	4
57	1·7412773	1·7859817	1·8336152	1·8844489	1·9387889	1·9969823	3
58	1·7419997	1·7867508	1·8344354	1·8853249	1·9397262	1·9979870	2
59	1·7427229	1·7875208	1·8352565	1·8862019	1·9406646	1·9989929	1
60	1·7434468	1·7882916	1·8360785	1·8870799	1·9416040	2·0000000	0
′	35°	34°	33°	32°	31°	30°	′

COSECANTS.

SECANTS.

′	60°	61°	62°	63°	64°	65°	′
0	2·0000000	2·0626653	2·1300545	2·2026893	2·2811720	2·3662016	60
1	2·0010083	2·0637484	2·1312205	2·2039476	2·2825335	2·3676787	59
2	2·0020177	2·0648328	2·1323880	2·2052075	2·2838967	2·3691578	58
3	2·0030283	2·0659186	2·1335570	2·2064691	2·2852618	2·3706390	57
4	2·0040403	2·0670056	2·1347274	2·2077323	2·2866286	2·3721222	56
5	2·0050533	2·0680940	2·1358993	2·2089972	2·2879974	2·3736075	55
6	2·0060674	2·0691836	2·1370726	2·2102637	2·2893679	2·3750949	54
7	2·0070828	2·0702746	2·1382475	2·2115318	2·2907403	2·3765843	53
8	2·0080994	2·0713670	2·1394238	2·2128016	2·2921145	2·3780758	52
9	2·0091172	2·0724606	2·1406015	2·2140730	2·2934906	2·3795694	51
10	2·0101363	2·0735556	2·1417808	2·2153460	2·2948685	2·3810650	50
11	2·0111564	2·0746519	2·1429615	2·2166208	2·2962483	2·3825627	49
12	2·0121779	2·0757496	2·1441438	2·2178971	2·2976299	2·3840625	48
13	2·0132005	2·0768486	2·1453275	2·2191752	2·2990134	2·3855645	47
14	2·0142243	2·0779489	2·1465127	2·2204548	2·3003988	2·3870685	46
15	2·0152494	2·0790506	2·1476993	2·2217362	2·3017860	2·3885746	45
16	2·0162756	2·0801536	2·1488875	2·2230192	2·3031751	2·3900828	44
17	2·0173031	2·0812580	2·1500772	2·2243039	2·3045660	2·3915931	43
18	2·0183318	2·0823637	2·1512684	2·2255903	2·3059588	2·3931055	42
19	2·0193618	2·0834708	2·1524611	2·2268783	2·3073536	2·3946201	41
20	2·0203929	2·0845792	2·1536553	2·2281681	2·3087501	2·3961367	40
21	2·0214253	2·0856890	2·1548510	2·2294595	2·3101486	2·3976555	39
22	2·0224589	2·0868002	2·1560482	2·2307526	2·3115490	2·3991764	38
23	2·0234937	2·0879127	2·1572469	2·2320474	2·3129513	2·4006995	37
24	2·0245297	2·0890265	2·1584471	2·2333438	2·3143554	2·4022247	36
25	2·0255670	2·0901418	2·1596489	2·2346420	2·3157615	2·4037520	35
26	2·0266056	2·0912584	2·1608522	2·2359419	2·3171695	2·4052815	34
27	2·0276453	2·0923764	2·1620570	2·2372435	2·3185794	2·4068132	33
28	2·0286863	2·0934957	2·1632633	2·2385468	2·3199912	2·4083469	32
29	2·0297286	2·0946164	2·1644712	2·2398517	2·3214049	2·4098829	31
30	2·0307720	2·0957385	2·1656806	2·2411585	2·3228205	2·4114210	30
31	2·0318168	2·0968620	2·1668915	2·2424669	2·3242381	2·4129613	29
32	2·0328628	2·0979869	2·1681040	2·2437770	2·3256575	2·4145038	28
33	2·0339100	2·0991131	2·1693180	2·2450889	2·3270790	2·4160484	27
34	2·0349585	2·1002408	2·1705335	2·2464025	2·3285023	2·4175952	26
35	2·0360082	2·1013698	2·1717506	2·2477178	2·3299276	2·4191442	25
36	2·0370592	2·1025002	2·1729693	2·2490348	2·3313548	2·4206954	24
37	2·0381114	2·1036320	2·1741895	2·2503536	2·3327840	2·4222488	23
38	2·0391649	2·1047652	2·1754113	2·2516741	2·3342152	2·4238044	22
39	2·0402197	2·1058998	2·1766346	2·2529964	2·3356482	2·4253622	21
40	2·0412757	2·1070359	2·1778595	2·2543204	2·3370833	2·4269222	20
41	2·0423330	2·1081733	2·1790859	2·2556461	2·3385203	2·4284844	19
42	2·0433916	2·1093121	2·1803139	2·2569736	2·3399593	2·4300489	18
43	2·0444515	2·1104523	2·1815435	2·2583029	2·3414002	2·4316155	17
44	2·0455126	2·1115940	2·1827746	2·2596339	2·3428432	2·4331844	16
45	2·0465750	2·1127371	2·1840074	2·2609667	2·3442881	2·4347555	15
46	2·0476386	2·1138815	2·1852417	2·2623012	2·3457349	2·4363289	14
47	2·0487036	2·1150274	2·1864775	2·2636376	2·3471838	2·4379045	13
48	2·0497698	2·1161748	2·1877150	2·2649756	2·3486347	2·4394823	12
49	2·0508373	2·1173235	2·1889541	2·2663155	2·3500875	2·4410624	11
50	2·0519061	2·1184737	2·1901947	2·2676571	2·3515424	2·4426448	10
51	2·0529762	2·1196253	2·1914370	2·2690005	2·3529992	2·4442294	9
52	2·0540476	2·1207783	2·1926808	2·2703457	2·3544581	2·4458163	8
53	2·0551203	2·1219328	2·1939262	2·2716927	2·3559189	2·4474054	7
54	2·0561942	2·1230887	2·1951733	2·2730415	2·3573818	2·4489968	6
55	2·0572695	2·1242460	2·1964219	2·2743921	2·3588467	2·4505905	5
56	2·0583460	2·1254048	2·1976721	2·2757445	2·3603136	2·4521865	4
57	2·0594239	2·1265651	2·1989240	2·2770987	2·3617826	2·4537848	3
58	2·0605031	2·1277267	2·2001775	2·2784546	2·3632535	2·4553853	2
59	2·0615836	2·1288899	2·2014326	2·2798124	2·3647265	2·4569882	1
60	2·0626653	2·1300545	2·2026893	2·2811720	2·3662016	2·4585933	0
′	29°	28°	27°	26°	25°	24°	′

COSECANTS.

SECANTS.

′	66°	67°	68°	69°	70°	71°	′
0	2·4585933	2·5593047	2·6694672	2·7904281	2·9238044	3·0715535	60
1	2·4602008	2·5610599	2·6713906	2·7925444	2·9261431	3·0741507	59
2	2·4618106	2·5628176	2·6733171	2·7946641	2·9284888	3·0767525	58
3	2·4634227	2·5645781	2·6752465	2·7967873	2·9308326	3·0793590	57
4	2·4650371	2·5663412	2·6771790	2·7989140	2·9331833	3·0819703	56
5	2·4666538	2·5681069	2·6791145	2·8010441	2·9355380	3·0845660	55
6	2·4682729	2·5698752	2·6810530	2·8031777	2·9378908	3·0872068	54
7	2·4698943	2·5716162	2·6829945	2·8053148	2·9402597	3·0898319	53
8	2·4715181	2·5734199	2·6849391	2·8074554	2·9426263	3·0924620	52
9	2·4731442	2·5751963	2·6868867	2·8095995	2·9449975	3·0951067	51
10	2·4747726	2·5769753	2·6888374	2·8117471	2·9473725	3·0977563	50
11	2·4764034	2·5787570	2·6907912	2·8138982	2·9497516	3·1003805	49
12	2·4780366	2·5805414	2·6927480	2·8160529	2·9521348	3·1030296	48
13	2·4796721	2·5823284	2·6947079	2·8182111	2·9545221	3·1056835	47
14	2·4813100	2·5841182	2·6966709	2·8203729	2·9569135	3·1083423	46
15	2·4829503	2·5859107	2·6986370	2·8225382	2·9593090	3·1110057	45
16	2·4845929	2·5877058	2·7006061	2·8247071	2·9617087	3·1136740	44
17	2·4862380	2·5895037	2·7025784	2·8268796	2·9641125	3·1163473	43
18	2·4878854	2·5913048	2·7045588	2·8290556	2·9665205	3·1190252	42
19	2·4895352	2·5931077	2·7065328	2·8312353	2·9689327	3·1217081	41
20	2·4911874	2·5949137	2·7085139	2·8334185	2·9713490	3·1243959	40
21	2·4928421	2·5967225	2·7104987	2·8356054	2·9737695	3·1270886	39
22	2·4944991	2·5985341	2·7124866	2·8377938	2·9761942	3·1297863	38
23	2·4961586	2·6003484	2·7144777	2·8399899	2·9786231	3·1324887	37
24	2·4978204	2·6021654	2·7164719	2·8421877	2·9810563	3·1351962	36
25	2·4994848	2·6039852	2·7184693	2·8443891	2·9834936	3·1379086	35
26	2·5011515	2·6058078	2·7204698	2·8465941	2·9859352	3·1406259	34
27	2·5028207	2·6076332	2·7224735	2·8488028	2·9883811	3·1433483	33
28	2·5044923	2·6094613	2·7244804	2·8510152	2·9908312	3·1460756	32
29	2·5061663	2·6112922	2·7264905	2·8532312	2·9932856	3·1488079	31
30	2·5078428	2·6131259	2·7285038	2·8554510	2·9957443	3·1515453	30
31	2·5095218	2·6149624	2·7305203	2·8576744	2·9982073	3·1542877	29
32	2·5112032	2·6168018	2·7325400	2·8599015	3·0006746	3·1570351	28
33	2·5128871	2·6186439	2·7345630	2·8621324	3·0031462	3·1597876	27
34	2·5145735	2·6204888	2·7365892	2·8643670	3·0056221	3·1625452	26
35	2·5162624	2·6223366	2·7386186	2·8666053	3·0081024	3·1653078	25
36	2·5179537	2·6241872	2·7406512	2·8688474	3·0105870	3·1680756	24
37	2·5196475	2·6260406	2·7426871	2·8710932	3·0130760	3·1708484	23
38	2·5213438	2·6278960	2·7447263	2·8733428	3·0155694	3·1736264	22
39	2·5230426	2·6297560	2·7467687	2·8755961	3·0180672	3·1764093	21
40	2·5247440	2·6316180	2·7488144	2·8778532	3·0205693	3·1791978	20
41	2·5264478	2·6334828	2·7508634	2·8801142	3·0230759	3·1819913	19
42	2·5281541	2·6353506	2·7529157	2·8823789	3·0255868	3·1847890	18
43	2·5298630	2·6372211	2·7549712	2·8846474	3·0281023	3·1875937	17
44	2·5315744	2·6390946	2·7570301	2·8869198	3·0306221	3·1904028	16
45	2·5332883	2·6409710	2·7590923	2·8891960	3·0331464	3·1932170	15
46	2·5350048	2·6428502	2·7611578	2·8914760	3·0356752	3·1960365	14
47	2·5367238	2·6447323	2·7632267	2·8937598	3·0382084	3·1988613	13
48	2·5384453	2·6466174	2·7652988	2·8960475	3·0407462	3·2016913	12
49	2·5401694	2·6485054	2·7673744	2·8983391	3·0432884	3·2045266	11
50	2·5418961	2·6503962	2·7694532	2·9006346	3·0458352	3·2073673	10
51	2·5436253	2·6522901	2·7715355	2·9029339	3·0483864	3·2102132	9
52	2·5453571	2·6541868	2·7736211	2·9052372	3·0509423	3·2130644	8
53	2·5470915	2·6560865	2·7757100	2·9075443	3·0535026	3·2159210	7
54	2·5488284	2·6579891	2·7778024	2·9098553	3·0560675	3·2187830	6
55	2·5505680	2·6598947	2·7798982	2·9121703	3·0586370	3·2216503	5
56	2·5523101	2·6618033	2·7819973	2·9144892	3·0612111	3·2245230	4
57	2·5540548	2·6637148	2·7840999	2·9168121	3·0637898	3·2274011	3
58	2·5558022	2·6656292	2·7862059	2·9191389	3·0663731	3·2302846	2
59	2·5575521	2·6675467	2·7883153	2·9214697	3·0689610	3·2331736	1
60	2·5593047	2·6694672	2·7904281	2·9238044	3·0715535	3·2360680	0
′	23°	22°	21°	20°	19°	18°	′

COSECANTS.

SECANTS.

′	72°	73°	74°	75°	76°	77°	′
0	3·2360680	3·4203036	3·6279553	3·8637033	4·1335655	4·4454115	60
1	3·2389678	3·4235611	3·6316395	3·8679025	4·1383939	4·4510198	59
2	3·2418732	3·4268251	3·6353316	3·8721112	4·1432339	4·4566428	58
3	3·2447840	3·4300956	3·6390315	3·8763293	4·1480856	4·4622803	57
4	3·2477003	3·4333727	3·6427392	3·8805570	4·1529491	4·4679324	56
5	3·2506222	3·4366563	3·6464548	3·8847942	4·1578243	4·4735993	55
6	3·2535496	3·4399465	3·6501783	3·8890411	4·1627114	4·4792810	54
7	3·2564825	3·4432433	3·6539097	3·8932976	4·1676102	4·4849775	53
8	3·2594211	3·4465467	3·6576491	3·8975637	4·1725210	4·4906889	52
9	3·2623652	3·4498568	3·6613964	3·9018395	4·1774438	4·4964152	51
10	3·2653149	3·4531735	3·6651518	3·9061250	4·1823785	4·5021565	50
11	3·2682702	3·4564969	3·6689151	3·9104203	4·1873252	4·5079129	49
12	3·2712311	3·4598269	3·6726865	3·9147254	4·1922840	4·5136844	48
13	3·2741977	3·4631637	3·6764660	3·9190403	4·1972549	4·5194711	47
14	3·2771700	3·4665073	3·6802536	3·9233651	4·2022380	4·5252730	46
15	3·2801479	3·4698576	3·6840493	3·9276997	4·2072333	4·5310903	45
16	3·2831316	3·4732146	3·6878532	3·9320443	4·2122408	4·5369229	44
17	3·2861209	3·4765785	3·6916652	3·9363988	4·2172606	4·5427709	43
18	3·2891160	3·4799492	3·6954854	3·9407633	4·2222928	4·5486344	42
19	3·2921168	3·4833267	3·6993139	3·9451379	4·2273373	4·5545134	41
20	3·2951234	3·4867110	3·7031506	3·9495224	4·2323943	4·5604080	40
21	3·2981357	3·4901023	3·7069956	3·9539171	4·2374637	4·5663183	39
22	3·3011539	3·4935004	3·7108489	3·9583219	4·2425457	4·5722444	38
23	3·3041778	3·4969055	3·7147105	3·9627369	4·2476402	4·5781862	37
24	3·3072076	3·5003175	3·7185805	3·9671621	4·2527474	4·5841439	36
25	3·3102432	3·5037365	3·7224589	3·9715975	4·2578671	4·5901174	35
26	3·3132847	3·5071625	3·7263457	3·9760431	4·2629996	4·5961070	34
27	3·3163320	3·5105954	3·7302409	3·9804991	4·2681449	4·6021126	33
28	3·3193853	3·5140354	3·7341446	3·9849654	4·2733029	4·6081343	32
29	3·3224444	3·5174824	3·7380568	3·9894421	4·2784738	4·6141722	31
30	3·3255095	3·5209365	3·7419775	3·9939292	4·2836576	4·6202263	30
31	3·3285805	3·5243977	3·7459068	3·9984267	4·2888543	4·6262967	29
32	3·3316575	3·5278660	3·7498447	4·0029347	4·2940640	4·6323835	28
33	3·3347405	3·5313414	3·7537911	4·0074533	4·2992867	4·6384867	27
34	3·3378294	3·5348240	3·7577463	4·0119823	4·3045225	4·6446064	26
35	3·3409244	3·5383138	3·7617100	4·0165219	4·3097715	4·6507427	25
36	3·3440254	3·5418107	3·7656824	4·0210722	4·3150336	4·6568956	24
37	3·3471324	3·5453149	3·7696636	4·0256332	4·3203090	4·6630652	23
38	3·3502455	3·5488263	3·7736535	4·0302048	4·3255977	4·6692516	22
39	3·3533647	3·5523450	3·7776522	4·0347872	4·3308996	4·6754548	21
40	3·3564900	3·5558710	3·7816596	4·0393804	4·3362150	4·6816748	20
41	3·3596214	3·5594042	3·7856760	4·0439844	4·3415438	4·6879119	19
42	3·3627589	3·5629448	3·7897011	4·0485992	4·3468861	4·6941660	18
43	3·3659026	3·5664928	3·7937352	4·0532249	4·3522419	4·7004372	17
44	3·3690524	3·5700481	3·7977782	4·0578615	4·3576113	4·7067256	16
45	3·3722084	3·5736108	3·8018301	4·0625091	4·3629943	4·7130313	15
46	3·3753707	3·5771810	3·8058911	4·0671677	4·3683910	4·7193542	14
47	3·3785391	3·5807586	3·8099610	4·0718374	4·3738015	4·7256945	13
48	3·3817138	3·5843437	3·8140399	4·0765181	4·3792257	4·7320524	12
49	3·3848948	3·5879362	3·8181280	4·0812100	4·3846638	4·7384277	11
50	3·3880820	3·5915363	3·8222251	4·0859130	4·3901158	4·7448206	10
51	3·3912755	3·5951439	3·8263313	4·0906272	4·3955817	4·7512312	9
52	3·3944754	3·5987590	3·8304467	4·0953526	4·4010616	4·7576596	8
53	3·3976816	3·6023818	3·8345713	4·1000893	4·4065556	4·7641058	7
54	3·4008941	3·6060121	3·8387052	4·1048374	4·4120637	4·7705699	6
55	3·4041130	3·6096501	3·8428482	4·1095967	4·4175859	4·7770519	5
56	3·4073382	3·6132957	3·8470006	4·1143675	4·4231224	4·7835520	4
57	3·4105699	3·6169490	3·8511622	4·1191498	4·4286731	4·7900702	3
58	3·4138080	3·6206101	3·8553332	4·1239435	4·4342382	4·7966066	2
59	3·4170526	3·6242788	3·8595135	4·1287487	4·4398176	4·8031613	1
60	3·4203036	3·6279553	3·8637033	4·1335655	4·4454115	4·8097343	0
′	17°	16°	15°	14°	13°	12°	′

COSECANTS.

SECANTS.

′	78°	79°	80°	81°	82°	83°	′
0	4·8097343	5·2408431	5·7587705	6·3924532	7·1852965	8·2055090	60
1	4·8163258	5·2486979	5·7682867	6·4042154	7·2001996	8·2249952	59
2	4·8229357	5·2565768	5·7778350	6·4160216	7·2151653	8·2445748	58
3	4·8295643	5·2644798	5·7874158	6·4278719	7·2301940	8·2642485	57
4	4·8362114	5·2724070	5·7970230	6·4397666	7·2452859	8·2840171	56
5	4·8428774	5·2803587	5·8066732	6·4517059	7·2604417	8·3038812	55
6	4·8495621	5·2883347	5·8163510	6·4636901	7·2756616	8·3238415	54
7	4·8562657	5·2963354	5·8260617	6·4757195	7·2909460	8·3438986	53
8	4·8629883	5·3043608	5·8358053	6·4877944	7·3062954	8·3640534	52
9	4·8697299	5·3124109	5·8455820	6·4999148	7·3217102	8·3843065	51
10	4·8764907	5·3204860	5·8553921	6·5120812	7·3371909	8·4046586	50
11	4·8832707	5·3285861	5·8652356	6·5242938	7·3527377	8·4251105	49
12	4·8900700	5·3367114	5·8751128	6·5365528	7·3683512	8·4456629	48
13	4·8968886	5·3448620	5·8850238	6·5488586	7·3840318	8·4663165	47
14	4·9037267	5·3530379	5·8949688	6·5612113	7·3997798	8·4870721	46
15	4·9105844	5·3612393	5·9049479	6·5736112	7·4155959	8·5079304	45
16	4·9174616	5·3694664	5·9149614	6·5860587	7·4314803	8·5288923	44
17	4·9243586	5·3777192	5·9250095	6·5985540	7·4474335	8·5499584	43
18	4·9312754	5·3859979	5·9350922	6·6110973	7·4634560	8·5711295	42
19	4·9382120	5·3943026	5·9452098	6·6236890	7·4795482	8·5924065	41
20	4·9451687	5·4026333	5·9553625	6·6363293	7·4957106	8·6137901	40
21	4·9521453	5·4109903	5·9655504	6·6490184	7·5119437	8·6352812	39
22	4·9591421	5·4193737	5·9757737	6·6617568	7·5282478	8·6568805	38
23	4·9661591	5·4277835	5·9860326	6·6745446	7·5446236	8·6785889	37
24	4·9731964	5·4362199	5·9963274	6·6873822	7·5610713	8·7004071	36
25	4·9802541	5·4446831	6·0066581	6·7002699	7·5775916	8·7223361	35
26	4·9873323	5·4531731	6·0170250	6·7132079	7·5941849	8·7443766	34
27	4·9944311	5·4616901	6·0274282	6·7261965	7·6108516	8·7665295	33
28	5·0015505	5·4702342	6·0378680	6·7392360	7·6275923	8·7887957	32
29	5·0086907	5·4788056	6·0483445	6·7523268	7·6444075	8·8111761	31
30	5·0158517	5·4874043	6·0588580	6·7654691	7·6612976	8·8336715	30
31	5·0230337	5·4960305	6·0694085	6·7786632	7·6782631	8·8562828	29
32	5·0302367	5·5046843	6·0799964	6·7919095	7·6953047	8·8790109	28
33	5·0374607	5·5133659	6·0906219	6·8052082	7·7124227	8·9018567	27
34	5·0447060	5·5220754	6·1012850	6·8185597	7·7296176	8·9248211	26
35	5·0519726	5·5308129	6·1119861	6·8319642	7·7468901	8·9479051	25
36	5·0592606	5·5395786	6·1227253	6·8454222	7·7642406	8·9711095	24
37	5·0665701	5·5483726	6·1335028	6·8589338	7·7816697	8·9944354	23
38	5·0739012	5·5571951	6·1443189	6·8724995	7·7991778	9·0178837	22
39	5·0812539	5·5660460	6·1551736	6·8861195	7·8167656	9·0414553	21
40	5·0886284	5·5749258	6·1660674	6·8997942	7·8344335	9·0651512	20
41	5·0960248	5·5838343	6·1770003	6·9135239	7·8521821	9·0889725	19
42	5·1034431	5·5927719	6·1879725	6·9273089	7·8700120	9·1129200	18
43	5·1108835	5·6017386	6·1989843	6·9411496	7·8879238	9·1369949	17
44	5·1183461	5·6107345	6·2100359	6·9550464	7·9059179	9·1611980	16
45	5·1258309	5·6197599	6·2211275	6·9689994	7·9239950	9·1855305	15
46	5·1333381	5·6288148	6·2322594	6·9830092	7·9421556	9·2099934	14
47	5·1408677	5·6378995	6·2434316	6·9970760	7·9604003	9·2345877	13
48	5·1484199	5·6470140	6·2546446	7·0112001	7·9787298	9·2593145	12
49	5·1559948	5·6561584	6·2658984	7·0253820	7·9971445	9·2841749	11
50	5·1635924	5·6653331	6·2771933	7·0396220	8·0156450	9·3091699	10
51	5·1712128	5·6745380	6·2885295	7·0539205	8·0342321	9·3343006	9
52	5·1788563	5·6837734	6·2999073	7·0682777	8·0529062	9·3595682	8
53	5·1865228	5·6930393	6·3113269	7·0826941	8·0716681	9·3849738	7
54	5·1942125	5·7023360	6·3227884	7·0971700	8·0905182	9·4105184	6
55	5·2019254	5·7116636	6·3342923	7·1117059	8·1094573	9·4362033	5
56	5·2096618	5·7210223	6·3458386	7·1263019	8·1284860	9·4620296	4
57	5·2174216	5·7304121	6·3574276	7·1409587	8·1476048	9·4879984	3
58	5·2252050	5·7398333	6·3690595	7·1556764	8·1668145	9·5141110	2
59	5·2330121	5·7492861	6·3807347	7·1704556	8·1861157	9·5403686	1
60	5·2408431	5·7587705	6·3924532	7·1852965	8·2055090	9·5667722	0
′	11°	10°	9°	8°	7°	6°	′

COSECANTS.

SECANTS.

′	84°	85°	86°	87°	88°	89°	′
0	9·5667722	11·473713	14·335587	19·107323	28·653708	57·298688	60
1	9·5933318	11·511990	14·395471	19·212970	28·894398	58·269755	59
2	9·6200229	11·550523	14·455859	19·321816	29·139169	59·274308	58
3	9·6468724	11·589316	14·516757	19·430893	29·388124	60·314110	57
4	9·6738730	11·628372	14·578172	19·541187	29·641373	61·391050	56
5	9·7010260	11·667693	14·640109	19·652754	29·899026	62·507153	55
6	9·7283327	11·707282	14·702576	19·765604	30·161201	63·664595	54
7	9·7557944	11·747141	14·765580	19·879758	30·428017	64·863716	53
8	9·7834124	11·787274	14·829128	19·995241	30·699598	66·113036	52
9	9·8111880	11·827683	14·893226	20·112075	30·976074	67·409272	51
10	9·8391227	11·868370	14·957882	20·230284	31·257577	68·757360	50
11	9·8672176	11·909340	15·023103	20·349893	31·544246	70·160474	49
12	9·8954744	11·950595	15·088896	20·470926	31·836225	71·622052	48
13	9·9238943	11·992137	15·155270	20·593409	32·133663	73·145827	47
14	9·9524787	12·033970	15·222231	20·717368	32·436713	74·735856	46
15	9·9812291	12·076098	15·289788	20·842830	32·745537	76·396554	45
16	10·010147	12·118523	15·357949	20·969824	33·060300	78·132742	44
17	10·039234	12·161246	15·426721	21·098376	33·381176	79·949684	43
18	10·068491	12·204274	15·496114	21·228515	33·708345	81·853150	42
19	10·097920	12·247608	15·566135	21·360272	34·041994	83·849470	41
20	10·127522	12·291252	15·636793	21·493676	34·382316	85·945609	40
21	10·157300	12·335210	15·708096	21·628759	34·729515	88·149244	39
22	10·187254	12·379484	15·780054	21·765553	35·083800	90·468863	38
23	10·217386	12·424078	15·852676	21·904090	35·445391	92·913869	37
24	10·247697	12·468995	15·925971	22·044403	35·814517	95·494711	36
25	10·278190	12·514240	15·999948	22·186528	36·191414	98·223033	35
26	10·308866	12·559815	16·074617	22·330499	36·576332	101·11185	34
27	10·339726	12·605724	16·149987	22·476353	36·969528	104·17574	33
28	10·370772	12·651971	16·226069	22·624126	37·371273	107·43114	32
29	10·402007	12·698560	16·302873	22·773857	37·781849	110·89656	31
30	10·433431	12·745495	16·380408	22·925586	38·201550	114·59301	30
31	10·465046	12·792779	16·458686	23·079351	38·630683	118·54440	29
32	10·496854	12·840416	16·537717	23·235196	39·069571	122·77803	28
33	10·528857	12·888410	16·617512	23·393161	39·518549	127·32526	27
34	10·561057	12·936765	16·698082	23·553291	39·977969	132·22229	26
35	10·593455	12·985486	16·779439	23·715630	40·448201	137·51108	25
36	10·626054	13·034576	16·861594	23·880224	40·929630	143·24061	24
37	10·658854	13·084040	16·944559	24·047121	41·423660	149·46837	23
38	10·691859	13·133882	17·028346	24·216370	41·927717	156·26228	22
39	10·725070	13·184106	17·112966	24·388020	42·445245	163·70325	21
40	10·758488	13·234717	17·198434	24·562123	42·975713	171·88831	20
41	10·792117	13·285719	17·284761	24·738731	43·519612	180·93496	19
42	10·825957	13·337116	17·371960	24·917900	44·077458	190·98680	18
43	10·860011	13·388914	17·460046	25·099685	44·649795	202·22122	17
44	10·894281	13·441118	17·549030	25·284144	45·237195	214·85995	16
45	10·928768	13·493731	17·638928	25·471337	45·840360	229·18385	15
46	10·963476	13·546758	17·729753	25·661324	46·459625	245·55402	14
47	10·998406	13·600205	17·821520	25·854169	47·095961	264·44269	13
48	11·033560	13·654077	17·914243	26·049937	47·749974	286·47948	12
49	11·068940	13·708379	18·007937	26·248094	48·422411	312·52297	11
50	11·104549	13·763115	18·102619	26·450510	49·114062	343·77516	10
51	11·140389	13·818291	18·198303	26·655455	49·825762	381·97230	9
52	11·176462	13·873913	18·295005	26·863603	50·558396	429·71873	8
53	11·212770	13·929985	18·392742	27·075030	51·312902	491·10702	7
54	11·249316	13·986514	18·491530	27·289814	52·090272	572·95809	6
55	11·286101	14·043504	18·591387	27·508035	52·891564	687·54960	5
56	11·323129	14·100963	18·692330	27·729777	53·717896	859·43689	4
57	11·360402	14·158894	18·794377	27·955125	54·570464	1145·9157	3
58	11·397922	14·217304	18·897545	28·184168	55·450534	1718·8735	2
59	11·435692	14·276200	19·001854	28·416097	56·359462	3437·7468	1
60	11·473713	14·335587	19·107323	28·653708	57·298688	Infinite.	0
′	5°	4°	3°	2°	1°	0°	′

COSECANTS.

′	0°		1°		2°		3°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infinite.	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	1
60	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	89°		88°		87°		86°		

′	4° Tang	4° Cotang	5° Tang	5° Cotang	6° Tang	6° Cotang	7° Tang	7° Cotang	′
0	.06993	14.3007	.08749	11.4301	.10510	9.51436	.12278	8.14435	60
1	.07022	14.2411	.08778	11.3919	.10540	9.48781	.12308	8.12481	59
2	.07051	14.1821	.08807	11.3540	.10569	9.46141	.12338	8.10536	58
3	.07080	14.1235	.08837	11.3163	.10599	9.43515	.12367	8.08600	57
4	.07110	14.0655	.08866	11.2789	.10628	9.40904	.12397	8.06674	56
5	.07139	14.0079	.08895	11.2417	.10657	9.38307	.12426	8.04756	55
6	.07168	13.9507	.08925	11.2048	.10687	9.35724	.12456	8.02848	54
7	.07197	13.8940	.08954	11.1681	.10716	9.33155	.12485	8.00948	53
8	.07227	13.8378	.08983	11.1316	.10746	9.30599	.12515	7.99058	52
9	.07256	13.7821	.09013	11.0954	.10775	9.28058	.12544	7.97176	51
10	.07285	13.7267	.09042	11.0594	.10805	9.25530	.12574	7.95302	50
11	.07314	13.6719	.09071	11.0237	.10834	9.23016	.12603	7.93438	49
12	.07344	13.6174	.09101	10.9882	.10863	9.20516	.12633	7.91582	48
13	.07373	13.5634	.09130	10.9529	.10893	9.18028	.12662	7.89734	47
14	.07402	13.5098	.09159	10.9178	.10922	9.15554	.12692	7.87895	46
15	.07431	13.4566	.09189	10.8829	.10952	9.13093	.12722	7.86064	45
16	.07461	13.4039	.09218	10.8483	.10981	9.10646	.12751	7.84242	44
17	.07490	13.3515	.09247	10.8139	.11011	9.08211	.12781	7.82428	43
18	.07519	13.2996	.09277	10.7797	.11040	9.05789	.12810	7.80622	42
19	.07548	13.2480	.09306	10.7457	.11070	9.03379	.12840	7.78825	41
20	.07578	13.1969	.09335	10.7119	.11099	9.00983	.12869	7.77035	40
21	.07607	13.1461	.09365	10.6783	.11128	8.98598	.12899	7.75254	39
22	.07636	13.0958	.09394	10.6450	.11158	8.96227	.12929	7.73480	38
23	.07665	13.0458	.09423	10.6118	.11187	8.93867	.12958	7.71715	37
24	.07695	12.9962	.09453	10.5789	.11217	8.91520	.12988	7.69957	36
25	.07724	12.9469	.09482	10.5462	.11246	8.89185	.13017	7.68208	35
26	.07753	12.8981	.09511	10.5136	.11276	8.86862	.13047	7.66466	34
27	.07782	12.8496	.09541	10.4813	.11305	8.84551	.13076	7.64732	33
28	.07812	12.8014	.09570	10.4491	.11335	8.82252	.13106	7.63005	32
29	.07841	12.7536	.09600	10.4172	.11364	8.79964	.13136	7.61287	31
30	.07870	12.7062	.09629	10.3854	.11394	8.77689	.13165	7.59575	30
31	.07899	12.6591	.09658	10.3538	.11423	8.75425	.13195	7.57872	29
32	.07929	12.6124	.09688	10.3224	.11452	8.73172	.13224	7.56176	28
33	.07958	12.5660	.09717	10.2913	.11482	8.70931	.13254	7.54487	27
34	.07987	12.5199	.09746	10.2602	.11511	8.68701	.13284	7.52806	26
35	.08017	12.4742	.09776	10.2294	.11541	8.66482	.13313	7.51132	25
36	.08046	12.4288	.09805	10.1988	.11570	8.64275	.13343	7.49465	24
37	.08075	12.3838	.09834	10.1683	.11600	8.62078	.13372	7.47806	23
38	.08104	12.3390	.09864	10.1381	.11629	8.59893	.13402	7.46154	22
39	.08134	12.2946	.09893	10.1080	.11[illegible]	8.57718	.13432	7.44509	21
40	.08163	12.2505	.09923	10.0780	.11688	8.55555	.13461	7.42871	20
41	.08192	12.2067	.09952	10.0483	.11718	8.53402	.13491	7.41240	19
42	.08221	12.1632	.09981	10.0187	.11747	8.51259	.13521	7.39616	18
43	.08251	12.1201	.10011	9.98931	.11777	8.49128	.13550	7.37999	17
44	.08280	12.0772	.10040	9.96007	.11806	8.47007	.13580	7.36389	16
45	.08309	12.0346	.10069	9.93101	.11836	8.44896	.13609	7.34786	15
46	.08339	11.9923	.10099	9.90211	.11865	8.42795	.13639	7.33190	14
47	.08368	11.9504	.10128	9.87338	.11895	8.40705	.13669	7.31600	13
48	.08397	11.9087	.10158	9.84482	.11924	8.38625	.13698	7.30018	12
49	.08427	11.8673	.10187	9.81641	.11954	8.36555	.13728	7.28442	11
50	.08456	11.8262	.10216	9.78817	.11983	8.34496	.13758	7.26873	10
51	.08485	11.7853	.10246	8.76009	.12013	8.32446	.13787	7.25310	9
52	.08514	11.7448	.10275	9.73217	.12042	8.30406	.13817	7.23754	8
53	.08544	11.7045	.10305	9.70441	.12072	8.28376	.13846	7.22204	7
54	.08573	11.6645	.10334	9.67680	.12101	8.26355	.13876	7.20661	6
55	.08602	11.6248	.10363	9.64935	.12131	8.24345	.13906	7.19125	5
56	.08632	11.5853	.10393	9.62205	.12160	8.22344	.13935	7.17594	4
57	.08661	11.5461	.10422	9.59490	.12190	8.20352	.13965	7.16071	3
58	.08690	11.5072	.10452	9.56791	.12219	8.18370	.13995	7.14553	2
59	.08720	11.4685	.10481	9.54106	.12249	8.16398	.14024	7.13042	1
60	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	85°		84°		83°		82°		

′	8°		9°		10°		11°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.14054	7.11537	.15838	6.31375	.17633	5.67128	.19438	5.14455	60
1	.14084	7.10038	.15868	6.30189	.17663	5.66165	.19468	5.13658	59
2	.14113	7.08546	.15898	6.29007	.17693	5.65205	.19498	5.12862	58
3	.14143	7.07059	.15928	6.27829	.17723	5.64248	.19529	5.12069	57
4	.14173	7.05579	.15958	6.26655	.17753	5.63295	.19559	5.11279	56
5	.14202	7.04105	.15988	6.25486	.17783	5.62344	.19589	5.10490	55
6	.14232	7.02637	.16017	6.24321	.17813	5.61397	.19619	5.09704	54
7	.14262	7.01174	.16047	6.23160	.17843	5.60452	.19649	5.08921	53
8	.14291	6.99718	.16077	6.22003	.17873	5.59511	.19680	5.08139	52
9	.14321	6.98268	.16107	6.20851	.17903	5.58573	.19710	5.07360	51
10	.14351	6.96823	.16137	6.19703	.17933	5.57638	.19740	5.06584	50
11	.14381	6.95385	.16167	6.18559	.17963	5.56706	.19770	5.05809	49
12	.14410	6.93952	.16196	6.17419	.17993	5.55777	.19801	5.05037	48
13	.14440	6.92525	.16226	6.16283	.18023	5.54851	.19831	5.04267	47
14	.14470	6.91104	.16256	6.15151	.18053	5.53927	.19861	5.03499	46
15	.14499	6.89688	.16286	6.14023	.18083	5.53007	.19891	5.02734	45
16	.14529	6.88278	.16316	6.12899	.18113	5.52090	.19921	5.01971	44
17	.14559	6.86874	.16346	6.11779	.18143	5.51176	.19952	5.01210	43
18	.14588	6.85475	.16376	6.10664	.18173	5.50264	.19982	5.00451	42
19	.14618	6.84082	.16405	6.09552	.18203	5.49356	.20012	4.99695	41
20	.14648	6.82694	.16435	6.08444	.18233	5.48451	.20042	4.98940	40
21	.14678	6.81312	.16465	6.07340	.18263	5.47548	.20073	4.98188	39
22	.14707	6.79936	.16495	6.06240	.18293	5.46648	.20103	4.97438	38
23	.14737	6.78564	.16525	6.05143	.18323	5.45751	.20133	4.96690	37
24	.14767	6.77199	.16555	6.04051	.18353	5.44857	.20164	4.95945	36
25	.14796	6.75838	.16585	6.02962	.18384	5.43966	.20194	4.95201	35
26	.14826	6.74483	.16615	6.01878	.18414	5.43077	.20224	4.94460	34
27	.14856	6.73133	.16645	6.00797	.18444	5.42192	.20254	4.93721	33
28	.14886	6.71789	.16674	5.99720	.18474	5.41309	.20285	4.92984	32
29	.14915	6.70450	.16704	5.98646	.18504	5.40429	.20315	4.92249	31
30	.14945	6.69116	.16734	5.97576	.18534	5.39552	.20345	4.91516	30
31	.14975	6.67787	.16764	5.96510	.18564	5.38677	.20376	4.90785	29
32	.15005	6.66463	.16794	5.95448	.18594	5.37805	.20406	4.90056	28
33	.15034	6.65144	.16824	5.94390	.18624	5.36936	.20436	4.89330	27
34	.15064	6.63831	.16854	5.93335	.18654	5.36070	.20466	4.88605	26
35	.15094	6.62523	.16884	5.92283	.18684	5.35206	.20497	4.87882	25
36	.15124	6.61219	.16914	5.91236	.18714	5.34345	.20527	4.87162	24
37	.15153	6.59921	.16944	5.90191	.18745	5.33487	.20557	4.86444	23
38	.15183	6.58627	.16974	5.89151	.18775	5.32631	.20588	4.85727	22
39	.15213	6.57339	.17004	5.88114	.18805	5.31778	.20618	4.85013	21
40	.15243	6.56055	.17033	5.87080	.18835	5.30928	.20648	4.84300	20
41	.15272	6.54777	.17063	5.86051	.18865	5.30080	.20679	4.83590	19
42	.15302	6.53503	.17093	5.85024	.18895	5.29235	.20709	4.82882	18
43	.15332	6.52234	.17123	5.84001	.18925	5.28393	.20739	4.82175	17
44	.15362	6.50970	.17153	5.82982	.18955	5.27553	.20770	4.81471	16
45	.15391	6.49710	.17183	5.81966	.18986	5.26715	.20800	4.80769	15
46	.15421	6.48456	.17213	5.80953	.19016	5.25880	.20830	4.80068	14
47	.15451	6.47206	.17243	5.79944	.19046	5.25048	.20861	4.79370	13
48	.15481	6.45961	.17273	5.78938	.19076	5.24218	.20891	4.78673	12
49	.15511	6.44720	.17303	5.77936	.19106	5.23391	.20921	4.77978	11
50	.15540	6.43484	.17333	5.76937	.19136	5.22566	.20952	4.77286	10
51	.15570	6.42253	.17363	5.75941	.19166	5.21744	.20982	4.76595	9
52	.15600	6.41026	.17393	5.74949	.19197	5.20925	.21013	4.75906	8
53	.15630	6.39804	.17423	5.73960	.19227	5.20107	.21043	4.75219	7
54	.15660	6.38587	.17453	5.72974	.19257	5.19293	.21073	4.74534	6
55	.15689	6.37374	.17483	5.71992	.19287	5.18480	.21104	4.73851	5
56	.15719	6.36165	.17513	5.71013	.19317	5.17671	.21134	4.73170	4
57	.15749	6.34961	.17543	5.70037	.19347	5.16863	.21164	4.72490	3
58	.15779	6.33761	.17573	5.69064	.19378	5.16058	.21195	4.71813	2
59	.15809	6.32566	.17603	5.68094	.19408	5.15256	.21225	4.71137	1
60	.15838	6.31375	.17633	5.67128	.19438	5.14455	.21256	4.70463	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	81°		80°		79°		78°		

′	12°		13°		14°		15°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	60
1	.21286	4.69791	.23117	4.32573	.24964	4.00582	.26826	3.72771	59
2	.21316	4.69121	.23148	4.32001	.24995	4.00086	.26857	3.72338	58
3	.21347	4.68452	.23179	4.31430	.25026	3.99592	.26888	3.71907	57
4	.21377	4.67786	.23209	4.30860	.25056	3.99099	.26920	3.71476	56
5	.21408	4.67121	.23240	4.30291	.25087	3.98607	.26951	3.71046	55
6	.21438	4.66458	.23271	4.29724	.25118	3.98117	.26982	3.70616	54
7	.21469	4.65797	.23301	4.29159	.25149	3.97627	.27013	3.70188	53
8	.21499	4.65138	.23332	4.28595	.25180	3.97139	.27044	3.69761	52
9	.21529	4.64480	.23363	4.28032	.25211	3.96651	.27076	3.69335	51
10	.21560	4.63825	.23393	4.27471	.25242	3.96165	.27107	3.68909	50
11	.21590	4.63171	.23424	4.26911	.25273	3.95680	.27138	3.68485	49
12	.21621	4.62518	.23455	4.26352	.25304	3.95196	.27169	3.68061	48
13	.21651	4.61868	.23485	4.25795	.25335	3.94713	.27201	3.67638	47
14	.21682	4.61219	.23516	4.25239	.25366	3.94232	.27232	3.67217	46
15	.21712	4.60572	.23547	4.24685	.25397	3.93751	.27263	3.66796	45
16	.21743	4.59927	.23578	4.24132	.25428	3.93271	.27294	3.66376	44
17	.21773	4.59283	.23608	4.23580	.25459	3.92793	.27326	3.65957	43
18	.21804	4.58641	.23639	4.23030	.25490	3.92316	.27357	3.65538	42
19	.21834	4.58001	.23670	4.22481	.25521	3.91839	.27388	3.65121	41
20	.21864	4.57363	.23700	4.21933	.25552	3.91364	.27419	3.64705	40
21	.21895	4.56726	.23731	4.21387	.25583	3.90890	.27451	3.64289	39
22	.21925	4.56091	.23762	4.20842	.25614	3.90417	.27482	3.63874	38
23	.21956	4.55458	.23793	4.20298	.25645	3.89945	.27513	3.63461	37
24	.21986	4.54826	.23823	4.19756	.25676	3.89474	.27545	3.63048	36
25	.22017	4.54196	.23854	4.19215	.25707	3.89004	.27576	3.62636	35
26	.22047	4.53568	.23885	4.18675	.25738	3.88536	.27607	3.62224	34
27	.22078	4.52941	.23916	4.18137	.25769	3.88068	.27638	3.61814	33
28	.22108	4.52316	.23946	4.17600	.25800	3.87601	.27670	3.61405	32
29	.22139	4.51693	.23977	4.17064	.25831	3.87136	.27701	3.60996	31
30	.22169	4.51071	.24008	4.16530	.25862	3.86671	.27732	3 60588	30
31	.22200	4.50451	.24039	4.15997	.25893	3.86208	.27764	3.60181	29
32	.22231	4.49832	.24069	4.15465	.25924	3.85745	.27795	3.59775	28
33	.22261	4.49215	.24100	4.14934	.25955	3.85284	.27826	3.59370	27
34	.22292	4.48600	.24131	4.14405	.25986	3.84824	.27858	3.58966	26
35	.22322	4.47986	.24162	4.13877	.26017	3.84364	.27889	3.58562	25
36	.22353	4.47374	.24193	4.13350	.26048	3.83906	.27921	3.58160	24
37	.22383	4.46764	.24223	4.12825	.26079	3.83449	.27952	3.57758	23
38	.22414	4.46155	.24254	4.12301	.26110	3.82992	.27983	3.57357	22
39	.22444	4.45548	.24285	4.11778	.26141	3.82537	.28015	3.56957	21
40	.22475	4.44942	.24316	4.11256	.26172	3.82083	.28046	3.56557	20
41	.22505	4.44338	.24347	4.10736	.26203	3.81630	.28077	3.56159	19
42	.22536	4.43735	.24377	4.10216	.26235	3.81177	.28109	3.55761	18
43	.22567	4.43134	.24408	4.09699	.26266	3.80726	.28140	3.55364	17
44	.22597	4.42534	.24439	4.09182	.26297	3.80276	.28172	3.54968	16
45	.22628	4.41936	.24470	4.08666	.26328	3.79827	.28203	3.54573	15
46	.22658	4.41340	.24501	4.08152	.26359	3.79378	.28234	3.54179	14
47	.22689	4.40745	.24532	4.07639	.26390	3.78931	.28266	3.53785	13
48	.22719	4.40152	.24562	4.07127	.26421	3.78485	.28297	3.53393	12
49	.22750	4.39560	.24593	4.06616	.26452	3.78040	.28329	3.53001	11
50	.22781	4.38969	.24624	4.06107	.26483	3.77595	.28360	3.52609	10
51	.22811	4.38381	.24655	4.05599	.26515	3.77152	.28391	3.52219	9
52	.22842	4.37793	.24686	4.05092	.26546	3.76709	.28423	3.51829	8
53	.22872	4.37207	.24717	4.04586	.26577	3.76268	.28454	3.51441	7
54	.22903	4.36623	.24747	4.04081	.26608	3.75828	.28486	3.51053	6
55	.22934	4.36040	.24778	4.03578	.26639	3.75388	.28517	3.50666	5
56	.22964	4.35459	.24809	4.03076	.26670	3.74950	.28549	3.50279	4
57	.22995	4.34879	.24840	4.02574	.26701	3.74512	.28580	3.49894	3
58	.23026	4.34300	.24871	4.02074	.26733	3.74075	.28612	3.49509	2
59	.23056	4.33723	.24902	4.01576	.26764	3.73640	.28643	3.49125	1
60	.23087	4.33148	.24933	4.01078	.26795	3.73205	.28675	3.48741	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	77°		76°		75°		74°		

′	16°		17°		18°		19°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2.78523	15
46	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	73°		72°		71°		70°		

′	20°		21°		22°		23°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43239	2.31271	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	17
44	.37853	2.64177	.39862	2.50864	41899	2.38668	.43966	2.27447	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	5
56	.38253	2.61418	.40267	2 48340	.42310	2.36349	.44384	2.25309	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	69°		68°		67°		66°		

′	24°		25°		26°		27°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.44523	2.24604	.46631	2.14451	.48773	2.05030	.50953	1.96261	60
1	.44558	2.24428	.46666	2.14288	.48809	2.04879	.50989	1.96120	59
2	.44593	2.24252	.46702	2.14125	.48845	2.04728	.51026	1.95979	58
3	.44627	2.24077	.46737	2.13963	.48881	2.04577	.51063	1.95838	57
4	.44662	2.23902	.46772	2.13801	.48917	2.04426	.51099	1.95698	56
5	.44697	2.23727	.46808	2.13639	.48953	2.04276	.51136	1.95557	55
6	.44732	2.23553	.46843	2.13477	.48989	2.04125	.51173	1.95417	54
7	.44767	2.23378	.46879	2.13316	.49026	2.03975	.51209	1.95277	53
8	.44802	2.23204	.46914	2.13154	.49062	2.03825	.51246	1.95137	52
9	.44837	2.23030	.46950	2.12993	.49098	2.03675	.51283	1.94997	51
10	.44872	2.22857	.46985	2.12832	.49134	2.03526	.51319	1.94858	50
11	.44907	2.22683	.47021	2.12671	.49170	2.03376	.51356	1.94718	49
12	.44942	2.22510	.47056	2.12511	.49206	2.03227	.51393	1.94579	48
13	.44977	2.22337	.47092	2.12350	.49242	2.03078	.51430	1.94440	47
14	.45012	2.22164	.47128	2.12190	.49278	2.02929	.51467	1.94301	46
15	.45047	2.21992	.47163	2.12030	.49315	2.02780	.51503	1.94162	45
16	.45082	2.21819	.47199	2.11871	.49351	2.02631	.51540	1.94023	44
17	.45117	2.21647	.47234	2.11711	.49387	2.02483	.51577	1.93885	43
18	.45152	2.21475	.47270	2.11552	.49423	2.02335	.51614	1.93746	42
19	.45187	2.21304	.47305	2.11392	.49459	2.02187	.51651	1.93608	41
20	.45222	2.21132	.47341	2.11233	.49495	2.02039	.51688	1.93470	40
21	.45257	2.20961	.47377	2.11075	.49532	2.01891	.51724	1.93332	39
22	.45292	2.20790	.47412	2.10916	.49568	2.01743	.51761	1.93195	38
23	.45327	2.20619	.47448	2.10758	.49604	2.01596	.51798	1.93057	37
24	.45362	2.20449	.47483	2.10600	.49640	2.01449	.51835	1.92920	36
25	.45397	2.20278	.47519	2.10442	.49677	2.01302	.51872	1.92782	35
26	.45432	2.20108	.47555	2.10284	.49713	2.01155	.51909	1.92645	34
27	.45467	2.19938	.47590	2.10126	.49749	2.01008	.51946	1.92508	33
28	.45502	2.19769	.47626	2.09969	.49786	2.00862	.51983	1.92371	32
29	.45538	2.19599	.47662	2.09811	.49822	2.00715	.52020	1.92235	31
30	.45573	2.19430	.47698	2.09654	.49858	2.00569	.52057	1.92098	30
31	.45608	2.19261	.47733	2.09498	.49894	2.00423	.52094	1.91962	29
32	.45643	2.19092	.47769	2.09341	.49931	2.00277	.52131	1.91826	28
33	.45678	2.18923	.47805	2.09184	.49967	2.00131	.52168	1.91690	27
34	.45713	2.18755	.47840	2.09028	.50004	1.99986	.52205	1.91554	26
35	.45748	2.18587	.47876	2.08872	.50040	1.99841	.52242	1.91418	25
36	.45784	2.18419	.47912	2.08716	.50076	1.99695	.52279	1.91282	24
37	.45819	2.18251	.47948	2.08560	.50113	1.99550	.52316	1.91147	23
38	.45854	2.18084	.47984	2.08405	.50149	1.99406	.52353	1.91012	22
39	.45889	2.17916	.48019	2.08250	.50185	1.99261	.52390	1.90876	21
40	.45924	2.17749	.48055	2.08094	.50222	1.99116	.52427	1.90741	20
41	.45960	2.17582	.48091	2.07939	.50258	1.98972	.52464	1.90607	19
42	.45995	2.17416	.48127	2.07785	.50295	1.98828	.52501	1.90472	18
43	.46030	2.17249	.48163	2.07630	.50331	1.98684	.52538	1.90337	17
44	.46065	2.17083	.48198	2.07476	.50368	1.98540	.52575	1.90203	16
45	.46101	2.16917	.48234	2.07321	.50404	1.98396	.52613	1.90069	15
46	.46136	2.16751	.48270	2.07167	.50441	1.98253	.52650	1.89935	14
47	.46171	2.16585	.48306	2.07014	.50477	1.98110	.52687	1.89801	13
48	.46206	2.16420	.48342	2.06860	.50514	1.97966	.52724	1.89667	12
49	.46242	2.16255	.48378	2.06706	.50550	1.97823	.52761	1.89533	11
50	.46277	2.16090	.48414	2.06553	.50587	1.97681	.52798	1.89400	10
51	.46312	2.15925	.48450	2.06400	.50623	1.97538	.52836	1.89266	9
52	.46348	2.15760	.48486	2.06247	.50660	1.97395	.52873	1.89133	8
53	.46383	2.15596	.48521	2.06094	.50696	1.97253	.52910	1.89000	7
54	.46418	2.15432	.48557	2.05942	.50733	1.97111	.52947	1.88867	6
55	.46454	2.15268	.48593	2.05790	.50769	1.96969	.52985	1.88734	5
56	.46489	2.15104	.48629	2.05637	.50806	1.96827	.53022	1.88602	4
57	.46525	2.14940	.48665	2.05485	.50843	1.96685	.53059	1.88469	3
58	.46560	2.14777	.48701	2.05333	.50879	1.96544	.53096	1.88337	2
59	.46595	2.14614	.48737	2.05182	.50916	1.96402	.53134	1.88205	1
60	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	65°		64°		63°		62°		

′	28° Tang	28° Cotang	29° Tang	29° Cotang	30° Tang	30° Cotang	31° Tang	31° Cotang	′
0	.53171	1.88073	.55431	1.80405	.57735	1.73205	.60086	1.66428	60
1	.53208	1.87941	.55469	1.80281	.57774	1.73089	.60126	1.66318	59
2	.53246	1.87809	.55507	1.80158	.57813	1.72973	.60165	1.66209	58
3	.53283	1.87677	.55545	1.80034	.57851	1.72857	.60205	1.66099	57
4	.53320	1.87546	.55583	1.79911	.57890	1.72741	.60245	1.65990	56
5	.53358	1.87415	.55621	1.79788	.57929	1.72625	.60284	1.65881	55
6	.53395	1.87283	.55659	1.79665	.57968	1.72509	.60324	1.65772	54
7	.53432	1.87152	.55697	1.79542	.58007	1.72393	.60364	1.65663	53
8	.53470	1.87021	.55736	1.79419	.58046	1.72278	.60403	1.65554	52
9	.53507	1.86891	.55774	1.79296	.58085	1.72163	.60443	1.65445	51
10	.53545	1.86760	.55812	1.79174	.58124	1.72047	.60483	1.65337	50
11	.53582	1.86630	.55850	1.79051	.58162	1.71932	.60522	1.65228	49
12	.53620	1.86499	.55888	1.78929	.58201	1.71817	.60562	1.65120	48
13	.53657	1.86369	.55926	1.78807	.58240	1.71702	.60602	1.65011	47
14	.53694	1.86239	.55964	1.78685	.58279	1.71588	.60642	1.64903	46
15	.53732	1.86109	.56003	1.78563	.58318	1.71473	.60681	1.64795	45
16	.53769	1.85979	.56041	1.78441	.58357	1.71358	.60721	1.64687	44
17	.53807	1.85850	.56079	1.78319	.58396	1.71244	.60761	1.64579	43
18	.53844	1.85720	.56117	1.78198	.58435	1.71129	.60801	1.64471	42
19	.53882	1.85591	.56156	1.78077	.58474	1.71015	.60841	1.64363	41
20	.53920	1.85462	.56194	1.77955	.58513	1.70901	.60881	1.64256	40
21	.53957	1.85333	.56232	1.77834	.58552	1.70787	.60921	1.64148	39
22	.53995	1.85204	.56270	1.77713	.58591	1.70673	.60960	1.64041	38
23	.54032	1.85075	.56309	1.77592	.58631	1.70560	.61000	1.63934	37
24	.54070	1.84946	.56347	1.77471	.58670	1.70446	.61040	1.63826	36
25	.54107	1.84818	.56385	1.77351	.58709	1.70332	.61080	1.63719	35
26	.54145	1.84689	.56424	1.77230	.58748	1.70219	.61120	1.63612	34
27	.54183	1.84561	.56462	1.77110	.58787	1.70106	.61160	1.63505	33
28	.54220	1.84433	.56501	1.76990	.58826	1.69992	.61200	1.63398	32
29	.54258	1.84305	.56539	1.76869	.58865	1.69879	.61240	1.63292	31
30	.54296	1.84177	.56577	1.76749	.58905	1.69766	.61280	1.63185	30
31	.54333	1.84049	.56616	1.76629	.58944	1.69653	.61320	1.63079	29
32	.54371	1.83922	.56654	1.76510	.58983	1.69541	.61360	1.62972	28
33	.54409	1.83794	.56693	1.76390	.59022	1.69428	.61400	1.62866	27
34	.54446	1.83667	.56731	1.76271	.59061	1.69316	.61440	1.62760	26
35	.54484	1.83540	.56769	1.76151	.59101	1.69203	.61480	1.62654	25
36	.54522	1.83413	.56808	1.76032	.59140	1.69091	.61520	1.62548	24
37	.54560	1.83286	.56846	1.75913	.59179	1.68979	.61561	1.62442	23
38	.54597	1.83159	.56885	1.75794	.59218	1.68866	.61601	1.62336	22
39	.54635	1.83033	.56923	1.75675	.59258	1.68754	.61641	1.62230	21
40	.54673	1.82906	.56962	1.75556	.59297	1.68643	.61681	1.62125	20
41	.54711	1.82780	.57000	1.75437	.59336	1.68531	.61721	1.62019	19
42	.54748	1.82654	.57039	1.75319	.59376	1.68419	.61761	1.61914	18
43	.54786	1.82528	.57078	1.75200	.59415	1.68308	.61801	1.61808	17
44	.54824	1.82402	.57116	1.75082	.59454	1.68196	.61842	1.61703	16
45	.54862	1.82276	.57155	1.74964	.59494	1.68085	.61882	1.61598	15
46	.54900	1.82150	.57193	1.74846	.59533	1.67974	.61922	1.61493	14
47	.54938	1.82025	.57232	1.74728	.59573	1.67863	.61962	1.61388	13
48	.54975	1.81899	.57271	1.74610	.59612	1.67752	.62003	1.61283	12
49	.55013	1.81774	.57309	1.74492	.59651	1.67641	.62043	1.61179	11
50	.55051	1.81649	.57348	1.74375	.59691	1.67530	.62083	1.61074	10
51	.55089	1.81524	.57386	1.74257	.59730	1.67419	.62124	1.60970	9
52	.55127	1.81399	.57425	1.74140	.59770	1.67309	.62164	1.60865	8
53	.55165	1.81274	.57464	1.74022	.59809	1.67198	.62204	1.60761	7
54	.55203	1.81150	.57503	1.73905	.59849	1.67088	.62245	1.60657	6
55	.55241	1.81025	.57541	1.73788	.59888	1.66978	.62285	1.60553	5
56	.55279	1.80901	.57580	1.73671	.59928	1.66867	.62325	1.60449	4
57	.55317	1.80777	.57619	1.73555	.59967	1.66757	.62366	1.60345	3
58	.55355	1.80653	.57657	1.73438	.60007	1.66647	.62406	1.60241	2
59	.55393	1.80529	.57696	1.73321	.60046	1.66538	.62446	1.60137	1
60	.55431	1.80405	.57735	1.73205	.60086	1.66428	.62487	1.60033	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	61°		60°		59°		58°		

′	32° Tang	32° Cotang	33° Tang	33° Cotang	34° Tang	34° Cotang	35° Tang	35° Cotang	′
0	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	60
1	.62527	1.59930	.64982	1.53888	.67493	1.48163	.70064	1.42726	59
2	.62568	1.59826	.65024	1.53791	.67536	1.48070	.70107	1.42638	58
3	.62608	1.59723	.65065	1.53693	.67578	1.47977	.70151	1.42550	57
4	.62649	1.59620	.65106	1.53595	.67620	1.47885	.70194	1.42462	56
5	.62689	1.59517	.65148	1.53497	.67663	1.47792	.70238	1.42374	55
6	.62730	1.59414	.65189	1.53400	.67705	1.47699	.70281	1.42286	54
7	.62770	1.59311	.65231	1.53302	.67748	1.47607	.70325	1.42198	53
8	.62811	1.59208	.65272	1.53205	.67790	1.47514	.70368	1.42110	52
9	.62852	1.59105	.65314	1.53107	.67832	1.47422	.70412	1.42022	51
10	.62892	1.59002	.65355	1.53010	.67875	1.47330	.70455	1.41934	50
11	.62933	1.58900	.65397	1.52913	.67917	1.47238	.70499	1.41847	49
12	.62973	1.58797	.65438	1.52816	.67960	1.47146	.70542	1.41759	48
13	.63014	1.58695	.65480	1.52719	.68002	1.47053	.70586	1.41672	47
14	.63055	1.58593	.65521	1.52622	.68045	1.46962	.70629	1.41584	46
15	.63095	1.58490	.65563	1.52525	.68088	1.46870	.70673	1.41497	45
16	.63136	1.58388	.65604	1.52429	.68130	1.46778	.70717	1.41409	44
17	.63177	1.58286	.65646	1.52332	.68173	1.46686	.70760	1.41322	43
18	.63217	1.58184	.65688	1.52235	.68215	1.46595	.70804	1.41235	42
19	.63258	1.58083	.65729	1.52139	.68258	1.46503	.70848	1.41148	41
20	.63299	1.57981	.65771	1.52043	.68301	1.46411	.70891	1.41061	40
21	.63340	1.57879	.65813	1.51946	.68343	1.46320	.70935	1.40974	39
22	.63380	1.57778	.65854	1.51850	.68386	1.46229	.70979	1.40887	38
23	.63421	1.57676	.65896	1.51754	.68429	1.46137	.71023	1.40800	37
24	.63462	1.57575	.65938	1.51658	.68471	1.46046	.71066	1.40714	36
25	.63503	1.57474	.65980	1.51562	.68514	1.45955	.71110	1.40627	35
26	.63544	1.57372	.66021	1.51466	.68557	1.45864	.71154	1.40540	34
27	.63584	1.57271	.66063	1.51370	.68600	1.45773	.71198	1.40454	33
28	.63625	1.57170	.66105	1.51275	.68642	1.45682	.71242	1.40367	32
29	.63666	1.57069	.66147	1.51179	.68685	1.45592	.71285	1.40281	31
30	.63707	1.56969	.66189	1.51084	.68728	1.45501	.71329	1.40195	30
31	.63748	1.56868	.66230	1.50988	.68771	1.45410	.71373	1.40109	29
32	.63789	1.56767	.66272	1.50893	.68814	1.45320	.71417	1.40022	28
33	.63830	1.56667	.66314	1.50797	.68857	1.45229	.71461	1.39936	27
34	.63871	1.56566	.66356	1.50702	.68900	1.45139	.71505	1.39850	26
35	.63912	1.56466	.66398	1.50607	.68942	1.45049	.71549	1.39764	25
36	.63953	1.56366	.66440	1.50512	.68985	1.44958	.71593	1.39679	24
37	.63994	1.56265	.66482	1.50417	.69028	1.44868	.71637	1.39593	23
38	.64035	1.56165	.66524	1.50322	.69071	1.44778	.71681	1.39507	22
39	.64076	1.56065	.66566	1.50228	.69114	1.44688	.71725	1.39421	21
40	.64117	1.55966	.66608	1.50133	.69157	1.44598	.71769	1.39336	20
41	.64158	1.55866	.66650	1.50038	.69200	1.44508	.71813	1.39250	19
42	.64199	1.55766	.66692	1.49944	.69243	1.44418	.71857	1.39165	18
43	.64240	1.55666	.66734	1.49849	.69286	1.44329	.71901	1.39079	17
44	.64281	1.55567	.66776	1.49755	.69329	1.44239	.71946	1.38994	16
45	.64322	1.55467	.66818	1.49661	.69372	1.44149	.71990	1.38909	15
46	.64363	1.55368	.66860	1.49566	.69416	1.44060	.72034	1.38824	14
47	.64404	1.55269	.66902	1.49472	.69459	1.43970	.72078	1.38738	13
48	.64446	1.55170	.66944	1.49378	.69502	1.43881	.72122	1.38653	12
49	.64487	1.55071	.66986	1.49284	.69545	1.43792	.72167	1.38568	11
50	.64528	1.54972	.67028	1.49190	.69588	1.43703	.72211	1.38484	10
51	.64569	1.54873	.67071	1.49097	.69631	1.43614	.72255	1.38399	9
52	.64610	1.54774	.67113	1.49003	.69675	1.43525	.72299	1.38314	8
53	.64652	1.54675	.67155	1.48909	.69718	1.43436	.72344	1.38229	7
54	.64693	1.54576	.67197	1.48816	.69761	1.43347	.72388	1.38145	6
55	.64734	1.54478	.67239	1.48722	.69804	1.43258	.72432	1.38060	5
56	.64775	1.54379	.67282	1.48629	.69847	1.43169	.72477	1.37976	4
57	.64817	1.54281	.67324	1.48536	.69891	1.43080	.72521	1.37891	3
58	.64858	1.54183	.67366	1.48442	.69934	1.42992	.72565	1.37807	2
59	.64899	1.54085	.67409	1.48349	.69977	1.42903	.72610	1.37722	1
60	.64941	1.53986	.67451	1.48256	.70021	1.42815	.72654	1.37638	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	57°		56°		55°		54°		

′	36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	
′	53°		52°		51°		50°		′

′	40° Tang	40° Cotang	41° Tang	41° Cotang	42° Tang	42° Cotang	43° Tang	43° Cotang	′
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	0
′	49° Cotang	49° Tang	48° Cotang	48° Tang	47° Cotang	47° Tang	46° Cotang	46° Tang	′

BLOCK: A grooved pulley, rotating on a pintle and mounted in a casing called a *shell*, which is furnished with a hook eye, or strap by which it may be attached to an object. They are used extensively for moving heavy weights. Blocks are of various forms, each having a particular name: *Single* or *Double Block*, *Differential Block*, *Fall-block*, *Purchase-block*, *Snatch-block*, *Standing Block*, *Tail-block*, etc.

BLOCK AND TACKLE: A term including the block and the rope rove through it, for hoisting or obtaining a purchase.

BLOCKINGS: Pieces of timber used to raise barrels, etc., off the ground.

BOLSTER: The resting-place of a truss-bridge on its pier or abutment, or a timber or th ck iron plate placed between the end of a bridge and its seat on the abutment.

BONING, in carpentry and masonry, is performed by placing two straight-edges on an object and sighting on their upper edges to see if they range. If they do not, the surface is said to be in *wind*.

BORE: The inner diameter of a pipe, hollow cylinder, etc.

BORROW-PIT: A pit dug in order to obtain material for an embankment.

BOULDER: A stone rounded by natural attrition; a rounded mass of rock transported from its original bed.

BREAK JOINT: So to overlap pieces that the joints shall not be in line.

BREAKING LOAD: The load or weight which will just produce fracture in a piece of material or structure.

BREAKWATER: A structure of stone or timber so placed as to break the force of the waves to protect an anchorage or harbor.

BREAST-WALL: One built to prevent the falling of a vertical face cut into the natural soil.

BRIDGE-TRUSS: A structure of thrust- and tension-pieces, forming a skeleton beam. It has several varieties.

BRITTLENESS: The inclination of a material to break suddenly under any stress.

BULKHEAD: A timber or other structure built along the sides of streams or rivers. The face of a wharf parallel to the stream.

BUTT: The name given to an ordinary door-hinge.

CALIBRE: The inner diameter or bore of pipes, etc.

CALIPERS: Compasses or dividers with curved legs for measuring outside and inside diameters.

CALK OR CAULK : To fill seams or joints with something to prevent leaking.

CAMBER : A slight upward curve given to a beam or truss to allow for settling.

CANT-HOOK : A lever and suspended hook for turning logs.

CANTILEVER : A projecting beam or bracket which, however it may be loaded, has the upper fibres in tension and the lower in compression. A bridge formed by projecting brackets which support a central portion.

CAUSEWAY : A raised footway or roadway.

CHAIRS : Castings used to support the ends of rails or timbers.

CHAMFER means much the same as bevel, but applies more especially when two edges are cut away so as to form either a chamfer groove or a projecting sharp edge.

CHIPPING-CHISEL : A cold-chisel with a slightly convex face and an angle of about 80°.

CHIPPING-PIECE : The projecting piece left on a forged surface, affording surplus metal for reduction to a line with the chipping-chisel.

The projecting piece of iron cast on the face of a piece of iron framing where it is intended to be fitted against another.

CHOCK : Any piece used for filling up a chance hole or vacancy.

CLEARING : Cutting down timber and brush.

CLEVIS : See Shackle.

COMPRESSION is the stress produced by pressure; it shortens the material to which it is applied and tends to cause rupture by crushing.

CORBEL : A horizontal projecting piece which assists in supporting one resting upon it which projects still farther.

COUNTERBRACE : The member of a truss which is designed to resist both tensile and compressive strains.

COUNTERSINK.—An enlargement of a hole to receive the head of a bolt, screw, rivet, etc. The sides of the hole are merely chamfered when it is to receive the head of an ordinary wood-screw. When a flat-head screw or bolt-head is to be let in flush with the surface a flat bottom is required.

COVERING-STONES : In culverts the large stones extending across the top from side to side and resting upon the walls.

CRAB : A winch on a movable frame with power gearing, used in connection with derricks and other non-permanent hoisting-machines.

CRADLE: Applied to various kinds of timber supports which partly enclose the mass sustained. The masonry built around and below the haunches of an arch in sewers.

CRANE: A machine for hoisting and lowering heavy weights.

CREST: The top part of a dam over which the water flows.

CREST RAILING: The railing surmounting the ridge of the roof of a building.

CROSS-STRAIN: See Transverse Stress.

CROWBAR: A bar of iron used as a lever for various purposes, often pointed at one end.

CURB: 1. A stone, timber, or iron structure formed inside a well to keep back the surrounding earth. 2. A broad, flat, circular ring of timber or iron placed under the bottoms of circular walls in wells, shafts, etc., to prevent unequal settlement. 3. The stones dividing the sidewalk from the carriage-way of streets.

CULVERT: A waterway or drain of masonry or earthenware or iron pipe beneath a road or canal.

CULLED: Assorted, picked out, selected.

CURTAIN-WALL is that part of the exterior walls of buildings extending from the line of the window-cap of one story to the line of the window-sill of the next story above.

CUTWATER OR STARLING: The projecting ends of a bridge-pier, etc., usually so shaped as to allow water, ice, etc., to strike them with but little injury.

DAM: A bank of earth or a structure of stone, timber, etc., constructed across a stream to store water.

DEAD LOAD: A load applied gradually and steadily.

DEADMAN: A log of wood placed firmly in the ground to serve as an anchor for the guys of derricks, etc.

DECK-BRIDGE: One in which the roadway is carried directly at the top-chord joints or on the upper chords themselves.

DEFLECTION is the bending caused by a transverse stress.

DUCTILITY is the property of being permanently elongated or drawn out.

DERRICK.—A form of hoisting-machine. The peculiar feature of a derrick, which distinguishes it from some other forms of hoisting machines, is that it has a boom stayed from a central post, which may be anchored but is usually stayed by guys.

A *derrick* has one leg, a *shears* or "A" derrick two, and a *gin* three. A *crane* has a post and jib. A *whin* or *whim* has a vertical axis on which a rope winds. The *capstan* has a vertical drum

for the rope, and is rotated by bars. The *windlass* and *winch* have a horizontal barrel. See also Gin-pole.

DIKE, DYKE : A levee or wall of earth to prevent the encroachment of water or to serve as a wharf or jetty. The construction varies considerably, according to purpose, exposure, and the nature of the foundation.

DOCK.—An artificial excavation or structure for containing a vessel for repairs, etc.

Docks are of various kinds.

Dry-dock: A dock from which the water is withdrawn after the vessel is floated in for repairs.

Wet-dock: Where vessels are placed to be loaded or unloaded.

DOG IRON : A short bar of iron, forming a kind of cramp, with its ends bent down at right angles and pointed, so as to hold together two pieces into which they are driven ; often used for temporary purposes.

DREDGING is the operation of excavating mud, silt, etc., from the bottom of rivers, harbors, etc. Machines of various form, according to the nature of the service, are employed, as the *dipper*-dredge, *clam-shell* or *grapple* dredge, *crane*-dredge, *suction* or *hydraulic* dredge, *ladder*- or *elevator* dredge, etc.

DRIFT-PIN · A round piece of steel, made slightly tapering, and used for drawing holes in two pieces fair or for enlarging the holes by being driven through them.

DUMP : An embankment where material is deposited from carts, cars, or barrows.

DUMP SCOW : A boat having a movable bottom or other contrivance for automatically discharging the load.

DUTCHMAN : The name given to a block or wedge of like material with the structure driven into a gap to hide the fault in a badly made joint.

EAVES : That portion of a roof which projects beyond the walls.

ESCARPMENT : A nearly vertical natural face of rock or soil.

EYE : A circular hole in a flat bar, etc., for receiving a pin, or for other purposes.

ELASTICITY The property which all materials have (in greater or less degree of perfection) of returning to their original figure after being disturbed (i. e., strained) by any kind of stress.

ELASTIC LIMIT of materials is defined as that point at which the deformation ceases to be proportional to the stress, or the point at which the rate of stretch (or other deformation) begins

to increase. It is also defined as the point at which the first permanent set becomes visible.

FALL: The rope used with pulleys in hoisting.

FACTOR OF SAFETY.—The ratio in which the breaking load exceeds the working load. The factors of safety recommended are:

	Dead Load.	Live Load.
For perfect materials and workmanship........	2	4
For good ordinary materials and workmanship:		
Metals..................................	3	6
Timber..................................	4 to 5	8 to 10
Masonry.................................	4	8

FALL AND TACKLE: The fall is the pulling end of the rope; the tackle is the blocks with the rope rove through them.

FALSE WORKS: Construction works to enable the erection of the main works. Among false works may be cited coffer-dams, bridge-centring, scaffolding, etc.

FASCINE: A cylindrical bundle or fagot of brushwood used in revetments of earthworks, in making river- and sea-walls, etc. They vary in size from 6 to 18 feet in length and 6 to 9 inches in diameter.

FEATHER-EDGED: Said of boards when one edge is thinner than the other.

FENDER: A piece for protecting one thing from being broken or injured by blows from another.

FENDER PILES: Piles driven to ward off floating bodies.

FISHING: Applied to a form of joint; uniting by clamping between two short pieces which cover the joint.

FLANGE: A projection from one end or from the body of a column pipe, beam, etc., for the purpose of securing it to another piece or to a support.

FLASH-BOARDS: Movable boards placed on the top of a dam or weir to retain the water of the stream when the flow is small.

FIRE-PROOF CONSTRUCTION.—"The term 'fire proof construction' applies to buildings in which all parts that carry weights, stairs, elevator-enclosures and their contents are made of incombustible material, and in which all metallic structural members are protected against the effects of fire by coverings of an incombustible and slow-heat-conducting material. As such will be considered brick, hollow tiles or burnt clay, porous terra-cotta, and two layers of plastering on metal lath.

"The term 'slow-burning construction' comprises all buildings in which the structural members are made wholly or in part of combustible material, but throughout which all materials shall be protected against injury from fire by coverings of incombustible, slow-heat-conducting materials." (Chicago Building Ordinances, 1893.)

FLASHINGS: Broad strips of sheet lead, copper, tin, etc., with one edge inserted into the joints of masonry an inch or two above the roof and projecting out several inches so as to be flattened down close to the roof to prevent rain from leaking through the joint between the roof and chimney, etc., which projects above it.

FLUSH: 1. A term signifying an unbroken or even surface. 2. To wash by turning on a sudden dash of water, as in cleansing sewers by means of flush-tanks.

FLUME: A ditch, trough, or other channel of moderate size for conducting water.

FOUNDATION: The bed or basis of a structure.

FOXTAIL: A thin wedge inserted into a slit at the lower end of a pin or bolt so that as the pin is driven down the wedge enters it and causes it to swell and hold more firmly.

FRAME: The skeleton of a structure; to put together pieces so as to form a frame.

FURRINGS: Pieces which are placed upon others which are too low merely to bring their upper surfaces up to a required level, as is often done with joists when one or more are too low; a kind of chock.

FUSIBILITY is the property of becoming fluid when subjected to heat. The temperature at which th s is effected differs in each metal, and is called the *melting-point*.

GASKET: Rope-yarn or hemp used for stuffing at the joints of water-pipes, etc.

GIN-POLE: A timber mast with four guys and a sheave at the top over which the hoist-line leads to a crab bolted three or four feet from the bottom.

GIRDER.—The name girder is generally applied to beams of iron and steel, whatever the form, either cast, solid, rolled, or built up of plates and angles or other shapes riveted together. A "riveted girder" means a girder made of plates and angles; a "girder-beam" means a girder made of a solid rolled beam; a "box-gir er" is composed of two girders joined together by cover-plates, etc.; a "double girder" signifies the use of two rolled beams in a girder.

GRUBBING : Removing roots and stumps from the surface.

GUSSETS : Plain triangular pieces of plate iron riveted by their vertical and horizontal legs to the sides, tops, and bottoms of box-girders, etc., for strengthening their angles.

GUY : A stay-rope passing from the top of a spar or mast to a post or anchor in the ground, as the guys of a derrick, etc.

HARDENING : The property of becoming very hard when heated and quenched.

HARDNESS is the property of resisting indentation or wear by friction.

HANDSPIKE : A loose bar forming a lever for lifting or shifting an object.

HARDPAN : Gravel cemented with clay, which it is sometimes necessary to blast.

HIP ROOF : One that slopes four ways, forming ridges or hips.

HOARDING : A temporary close fence of boards placed around a work in progress to exclude stragglers.

HORSE : A wooden bar with legs used for supporting a staging.

IMPOST : The upper part of a pier from which an arch springs.

JAM-NUT : An auxiliary nut screwed down upon another one to hold it in place; *check-nut, lock-nut.*

JACK : A raising instrument, consisting of an iron rack in connection with a short, stout timber which supports it, and worked by cog-wheels and a winch.

JACK SCREW : A lifting implement which acts by the rotation of a screw in a threaded socket.

JETTY : A construction of stone, wood, etc., projecting into the sea, and serving as a wharf or *pier* for shipping, or as a *mole* to protect a harbor.

JIB : The upper projecting arm of a crane, supported by the stay.

JIM-CROW : An implement for bending or straightening rails.

KERF : The opening or narrow slit made in sawing.

KNEE : A piece of metal or wood bent at an angle to serve as a bracket.

LAP : To place one piece upon another, with the edge of one reaching beyond that of the other.

LAP-WELDING : Welding together pieces that have first been lapped, in distinction to *butt-welding.*

LEAD : The length of haul from the pit to the dump.

LIGHT : A pane of window-glass.

LINING : The masonry walls and arch built in a tunnel.

LINTEL: A horizontal beam over an opening in a wall.

LIVE LOAD: A load which is applied suddenly.

LOAD: The weight upon a beam or structure; it may be either concentrated at the centre or other point or uniformly distributed.

LOCK (CANAL).—A canal-lock is a device by which boats are passed from one level to another. It consists of a basin between the levels, having a pair of gates at each end communicating with the respective level. The floor of the upper end is even with the upper level, and the lower floor with the lower level.

The parts of a lock are:

The *head-gate* and the *tail-gate*, which, with the *side walls*, enclose the lock-chamber. The gates are made of framing, with *leaf-planking* nailed and bolted thereto.

The *clap-sill* or *mitre-sill*, with two *branches*, is the framing against which the lower edge of the gate shuts.

The *hollow quoin* is the recess in the masonry occupied by the *heel-post* of the gate.

The *head-bay* is the canal above the lock.

The *tail bay* is the canal below the lock.

The *lift* is the amount of fall overcome by the lock.

The *lift-wall* is the wall at the foot of the head-gate.

LOUVRE: A kind of vertical window placed on the roofs of workshops, etc., and formed of slats which permit ventilation and exclude rain.

LUMBER: Sawed timber, either boards, plank, or squared pieces.

MALLEABILITY is the property of being permanently extensible in all directions by hammering or rolling.

MAUL: A large mallet of hardwood.

MILL CONSTRUCTION.—The term "mill construction" applies to buildings in which all the girders and joists supporting floors and roof have a sectional area of not less than 72 square inches, and above the joists of which there is laid a solid timber floor not less than 3¾ inches thick. Wooden posts in buildings of this class are to have an area of at least 100 square inches. Iron columns, girders, or beams must be protected by an incombustible slow-heat-conducting material, but the wooden posts, girders, and joists need not be covered. (Chicago Building Ordinances, 1893.)

MODULUS OR COEFFICIENT OF ELASTICITY is a number expressing the relation between the amount of extension or compression of a material and the load producing that extension or compression; it is obtained by dividing the stress in pounds per square

inch of sectional area by the elongation or contraction expressed as a fraction of the length of the specimen.

MUCK: Soft mud containing much vegetable matter.

MUCKING: Removing muck.

NEAT LINES: Those by which the work is laid out.

NEAT WORK: Work wrought to the neat lines.

NOSING: The slight projection upon the front edge of a step or window-sill.

OUT OF SQUARE: Askew, oblique.

OUT OF WIND: Perfectly straight or flat.

PLIABILITY: The ability of a body to change its form temporarily under different stresses.

PROOF LOAD: The greatest load that can be applied to a piece of material to prove or test it by straining it to the utmost extent without producing permanent deformation or injury.

PARGET: The plastering applied to the interior surface of chimneys.

PLANT: The tools and apparatus required in any operation.

PIG: An oblong mass of iron as run from the smelting-furnace.

PILE: Spars pointed at one end and driven into the ground (see Piles, page 215 *et seq.*). *Spile* is a corruption.

PILOT-NUT: A nut placed on a truss-pin to protect the thread and assist in guiding the pin while it is being driven.

PONY-TRUSS: A low truss, of short span, without overhead lateral bracing, and with the roadway carried at the bottom joints.

PRIMED: Having the first coat of paint or "priming" laid on.

PROFILE: A light wooden frame set up to guide workmen during construction; a longitudinal section through a roadway, etc.

QUICKSAND may be defined as a mass of sand, or of silt and argillaceous matter, intimately mixed with water, forming a semi-fluid, having all the properties of a fluid, but in a minor degree.

RAMP: An inclined platform used instead of steps. A concave sweep connecting a higher and lower portion of a railing, wall, etc.

RACKED BACK: Built in steps or offsets.

RAKED OUT: Cleaned out with a scraper.

RETURN: The termination of the drip-stone or hood-moulding of a door or window.

REVEAL: The sides of an opening for a doorway, window, etc., between the framework and the outer surface of the wall.

RESILIENCE is a term used to express the quantity of "work done" in deforming a piece of material up to the elastic limit by the application of any kind of stress.

SADDLE HEADS: Hollow castings resting on the heads of columns to sustain another series above and allow beams to pass through.

SCAFFOLD: A platform temporarily erected during the progress of a structure for the support of workmen and materials.

SCOW: A flat-bottomed, square-ended boat, employed for many purposes—carrying materials, supporting pile drivers, etc.

SCRIBE: To trim off the edge of a board, etc., so as to make it fit closely at all points to an irregular surface.

SEPARATORS: Thimbles or small pieces of iron inserted between girders to keep them apart.

SET (*n.*): A permanent bend or deflection produced by straining a beam beyond its limit of elasticity.

SET (*v.*): Hardened, as the hardening of cement.

SEWAGE: The matter borne off by a sewer.

SEWERAGE: The system of sewers.

SHACKLE OR CLEVIS: A link in a chain shaped like a U, and so arranged that by drawing out a bolt or pin which fits into two holes at the ends of the U the chain can be separated at that point. A U-shaped metallic strap used in connection with a pin to connect a draft chain or *tree* to a plough, etc.

SHIM: A piece of wood, stone, or iron let into a slack place to fill it out to a fair surface or line.

SHAFT: A vertical pit or well.

SHOES: Iron fittings at the ends of rafters, etc.

SHOOT: An inclined trough through which materials are slid.

SHORE: A prop.

SHEARING STRESS: The stress produced when one part of a body is forcibly pressed or pulled so as to tend to make it slide over another part.

SILT: Soft, fine mud.

SINKING: Digging a vertical shaft.

SIPHON OR DIVE-CULVERT: A culvert built in the shape of a U for carrying a stream under an obstacle and allowing it afterwards to rise again to its natural level.

SKID: Slanting timbers forming an inclined plane, used in loading or unloading heavy articles from a truck, wagon, etc.

SKELETON CONSTRUCTION: A framework of metal which transmits all the external and internal strains from the top of a building to the foundation.

SLINGS: Pieces of rope or chain put around stones, etc., for raising them by.

SLIP: The sliding down of the sides of earth cuts or embankments. A long, narrow water-space or dock between two wharves or piers.

SLUICE: A water-channel of masonry, wood, etc., furnished with gates to regulate the flow of the water.

SODDING.—The placing of grass sods on the slopes of embankments or other surfaces.

The sods are cut from their bed in long strips with a sharp spade or on a large scale with a paring-plough. The strips are rolled with the grass inward for transportation to the place of use. On slopes they are held in place by small pegs driven at suitable intervals, and are tamped or beaten down to a solid bearing with a square or oblong mallet, called a flattening-mallet. Ragged and torn edges are removed or pared with a curved knife.

SPANDREL-BEAM: See Beam.

SPLAY: A surface making with another an angle differing from a right angle.

SPILE.—The name spile is frequently but incorrectly given to piles.

A spile is a small plug of wood used for stopping the spile-hole of a barrel or cask. The spile-hole is a small aperture made in the cask when placed on tap, usually near the bung-hole, to afford ingress for the air in order to permit the contained liquid to flow freely.

SPLICE: To unite two pieces firmly together.

STAGE: The interval or distance between two platforms in shovelling, throwing, or lifting.

STIFFNESS OR RIGIDITY: The resistance offered by bodies to change of their form under stresses.

STONE BOAT: A flat-bottomed sled for hauling heavy stones for short distances.

STRENGTH: The resistance offered by materials to deformation.

STRESSES: *Stress* and *strain* are words often used indifferently, either to mean the alterations of figure produced in a body by any forces, or to mean the forces producing those alterations.

Materials are subject to the undermentioned stresses, which produce strains, and, when carried far enough, fracture as stated.

Stress.	Strain.	Mode of Fracture.
Tensile or pulling	Stretching Elongation	Tearing
Compressive or thrusting	Shortening Squeezing	Crushing
Transverse or bending	Bending	Breaking across
Shearing	Distortion	Cutting asunder
Torsional or twisting	Twisting	Twisting or wrenching asunder

STIRRUP: A pendant band of iron supporting girders.

STRINGERS: Longitudinal beams, generally used to support uniform loads.

STRUT: An oblique brace; the member of a truss which is compressed endwise.

STUD: A short, projecting pin.

STUD BOLT: A bolt with a screw cut upon each end, one end to be screwed permanently into something, and the other end to hold by a nut something else that may be required to be removed at times.

SUMP: A well dug at the lowest point of the work into which the rain and other water may be led and from which it is removed by pumps.

SWEDGED: Hammered with a swedge-hammer.

SWIVEL: A revolving link in a chain, consisting of a ring or hook ending in a headed pin which turns in a link.

TAMP: To compact loose earth by ramming; to fill up with sand, etc., the remainder of the hole in which an explosive has been placed for blasting.

TAP-BOLT: A bolt which simply passes into its socket without penetrating it.

TEMPLET: A form or pattern to guide workmen.

TEMPERING: Lowering the degree of hardness after hardening, by reheating and cooling at different temperatures.

TENSION is the stress produced by pulling. It elongates the material upon which it acts, and tends to cause rupture by tearing it asunder.

THICKENING-WASHERS: Additional washers used when the thread is not cut far enough on a bolt.

THIMBLE : A short piece of tube slipped over a rod to separate parts of a structure, as a post or chord.

THROUGH BRIDGE : One in which the roadway is carried directly at the bottom-chord joints, with lateral bracing overhead between the top-chord joints, thus enclosing a space through which the load passes.

TORSION : A twisting strain, which seldom occurs in building construction, though quite frequently in machinery.

TRANSVERSE STRESS is one caused by bending the material on which it acts, and it tends to break it across.

TRUSS.—A framed or jointed structure designed to act as a beam. It is composed of two longitudinal members called the *upper* and *lower chords*. The members which join the chords are called the *web members;* these comprise *struts*, *ties*, and *counter-braces*. The struts are sometimes called *posts* or columns. The spaces between the chord-joints are called *panels*.

TURNBUCKLE : A small fastening turning about a screw through its centre; a nut with a right- and left-hand screw for tightening up rods.

WASTE-WEIR — SPILLWAY : An overfall provided along a canal, reservoir, etc., at which the water may discharge itself in case of becoming too high by rain, etc.

WASTED : Thrown away.

WEB : The flat metallic surface connecting two or more ribs or flanges.

WEIR : An opening in the breast of a dam or an embankment to discharge the excess of water; also an opening used for measuring the quantity of water discharged.

WELD : The junction of two metals made by heating and hammering them together in connection with a flux.

WIND : Synonymous with twist, warp, etc.

WING-WALLS : The retaining walls which flare out from the ends of bridges, etc.

UNDERPINNING : Supports, temporary or permanent, introduced beneath a wall already constructed.

UPSET : Hammered back to thicken the end of an iron bar, as in forming an eye or head for a bolt.

VALLEY : A re-entrant angle formed by the intersection of two parts of a roof.

WALES : Longitudinal timbers placed on the sides of piles.

WARPED : Twisted ; out of line.

WASHERS: Broad pieces of metal surrounding a bolt, and placed between the faces of the timbers through which the bolt passes and the head and nut of the bolt so as to distribute the pressure over a larger surface, and prevent the timber from being crushed when the bolt is tightly screwed up.

YIELD-POINT is defined as that point at which the rate of stretch (or other deformation) begins to increase rapidly. The difference between the elastic limit, defined as the point at which the rate of stretch begins to increase, and the yield-point, at which the rate of stretch increases suddenly, may in some cases be considerable.

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